RECORDS

OF

GEOLOGICAL SURVEY OF INDIA.

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THE GEOLOGICAL SURVEY OF INDIA

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1918

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1917. [April

GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1916. BY H. H. HAYDEN, C.I.E., F.R.S., *Director*.

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DISPOSITION LIST.

1. During the period under report the officers of the Department were employed as follows :—

Superintendents.

MR. C. S. MIDDLEMISS .	Returned to headquarters from the field on the 11th February 1916. Appointed to officiate as Director, Geological Survey of India, from 2nd October to 12th November 1916.
MR. E. VREDENBURG .	At headquarters as Palæontologist. Deputed to report on the site of the proposed dam across the Sutlej at Bhakra from 23rd January to 3rd February 1916.
DR. L. L. FERMOR .	Services lent to the Railway Board in connection with the exploration of the Western portion of the Bokaro Coalfield from 1st January to 5th June 1916. June 7th—August 3rd visited Chromite deposits of Baluchistan. Granted privilege leave from 12th to 30th October 1916. Services placed at the disposal of the Railway Board with effect from the 1st November 1916.

Assistant Superintendents.

DR. G. E. PILGRIM .	On military duty.
MR. G. H. TIPPER .	On military duty.

MR. H. WALKER . .	Returned from the field on the 2nd June 1916. At headquarters.
DR. E. H. PASCOE .	On military duty.
MR. K. A. K. HALLOWES	Returned from the field on the 26th April 1916. Granted privilege leave for one month from the 19th September 1916. Posted to the Central Provinces and left for the field on the 2nd November 1916.
MR. G. DE P. COTTER .	At headquarters as Curator. Deputed to examine molybdenite occurrence at Kunavaram from 12th—25th January 1916. Investigated the Gondwana rocks of Johilla in Rewah from 29th September to 30th October 1916.
MR. J. C. BROWN .	On special duty in Tavoy in connection with wolfram; in charge of the Geological Survey of Tavoy and Mergui Districts.
MR. H. C. JONES . .	On military duty.
MR. A. M. HERON .	Transferred to Tavoy from Central India, Rajputana and Bombay party. Left Calcutta on 12th February 1916.
DR. M. STUART . .	Returned from the field on the 8th May 1916. Acted as Lecturer on Geology, College of Engineering, Poona, from 10th June to 30th September 1916. Granted privilege leave for 15 days from 18th October 1916. Posted to the Punjab and left for the field on the 28th November 1916.

MR. N. D. DARU . .	Services retransferred to the Geological Survey of India with effect from the 18th June 1916. Attached to the Central India, Rajputana and Bombay party and left for the field on the 1st December 1916.
MR. C. S. FOX . .	On military duty.
MR. R. W. PALMER .	On military duty.

Chemist.

DR. W. A. K. CHRISTIE	On military duty.

Artist.

MR. K. F. WATKINSON	At headquarters. Granted privilege leave for three months with effect from the 1st December 1916.

Sub-Assistants.

S. SETHU RAMA RAU .	Returned from the field on the 21st May 1916. Posted to Tavoy and left for the field on the 13th October 1916.
M. VINAYAK RAO . .	Returned from the field on the 24th March 1916. Granted privilege leave for one month from the 25th March 1916. Posted to Tavoy and left for the field on the 13th October 1916.

Assistant-Curator.

MR. A. K. BANERJEE .	Placed in charge of the Laboratory at Tavoy and left Calcutta on the 5th February 1916.

ADMINISTRATIVE CHANGES.

Appointment and Promotion.

2. Mr. C. S. Middlemiss, C.I.E., Superintendent, was appointed to officiate as Director, Geological Survey of India, during Dr. Hayden's absence on leave from 2nd October 1916.

Dr. H. H. Hayden returned from privilege leave and resumed his duties as Director, Geological Survey of India, with effect from the forenoon of the 13th November 1916.

Mr. C. S. Middlemiss reverted to his substantive appointment as Superintendent, with effect from the 13th November 1916.

Mr. E. Vredenburg was appointed Palæontologist with effect from the 1st January 1916.

Leave.

3. Dr. H. H. Hayden, C.I.E., Director, was granted privilege leave for 41 days from the 2nd October 1916.

Dr. L. L. Fermor was granted privilege leave from 12th to 30th October 1916.

Dr. M. Stuart was granted privilege leave for 15 days with effect from the 18th October 1916.

Mr. K. A. K. Hallowes was granted privilege leave for one month with effect from the 19th September 1916.

Mr. K. F. Watkinson was granted privilege leave for three months, with effect from the 1st December 1916.

Sub-Assistant Vinayak Rao was granted privilege leave for one month, with effect from the 25th March 1916.

MILITARY SERVICE.

4. I greatly regret to have to record the death, from wounds received in Mesopotamia, of Mr. R. C. Burton. An obituary notice has already been published in *Records*, Vol. XLVII. Of the remaining seven officers who took commissions, all were on active service throughout the year.

STUDENTS.

5. Babu Harendra Mohan Lahiri, M.Sc., holding a Post Graduate Scholarship from the Government of Bengal, worked under the supervision of the Palæontologist from the 11th July 1916.

PROFESSORSHIPS AND LECTURERSHIPS.

Calcutta.

6. Mr. G. de P. Cotter was Lecturer on Geology at the Presidency College throughout the year.

Poona.

7. Dr. M. Stuart was Lecturer on Geology at the Engineering College, Poona, from 10th June till 30th September 1916.

Madras.

8. Mr. N. D. Daru, whose services were transferred to the Madras Educational Service on June 23rd, 1914, resumed his appointment of Assistant Superintendent on June 18th, 1916.

PUBLICATIONS.

9. The publications issued during the year under review comprise one volume of *Records*, one of *Memoirs* and two memoirs of *Palæontologia Indica.*

LIBRARY.

10. The additions to the library during the year 1916 amounted to 2,621 volumes, of which 824 were acquired by purchase and 1,797 by presentation and exchange.

MUSEUM AND LABORATORY.

Curator.

11. Mr. G. de P. Cotter continued to act as Curator of the Geological Museum and Laboratory throughout the year.

Determinative work and analyses.

12. The number of specimens referred to the Curator for examination and report was 310, of which assays and analyses were made of 40. This included analyses of columbite, uranium ochre and a mineral of the chemical composition of hatchettolite (tantalo-niobate of uranium and the rare earths).

Meteorites.

13. Three meteorite falls were recorded in 1916. The first fall occurred at Ekh Khera village in the Bisauli tahsil of the Budaun district, Rohilkhand (lat. 28° 16′; long. 78° 49′ 20″). Of this fall one piece only was received, weighing 841·1 grammes, and having the greater part of its surface covered with crust. It has been described by Mr. H. Walker (*Rec. Geol. Surv. Ind.*, XLVII, 273), who determines it to be a veined intermediate chondrite. The meteorite fell at 2-30 A.M. on the 5th of April, 1916. The second fall took place at Sultanpur village in the Ballia district, United Provinces (lat. 25° 55′ 30″; long. 84° 16′ 40″) at 11 A.M. on the 10th of July, 1916. Five fragments in all were recovered weighing respectively 328·71

grammes, 184·70 grammes, 340·55 grammes, 270·05 grammes, and 486·56 grammes. Mr. Walker has described this fall as follows :—"Sultanpur is a black chondrite (Cs), and is probably comparable with the McKinney fall. There is very little of the true crust left, but what remains is in small irregular patches which give a fused cindery appearance. Underneath the crust the surface is polished." The third fall was recorded from Rampurhat village, Birbhum district, and consists of one stone weighing 99·93 grammes and being almost completely covered with crust. Mr. Walker describes it as "an almost perfect specimen with no entirely unfused portion visible. There is evidence at one corner that it consists partly of chondrules, possibly of olivine. From the appearance of the crust it seems probable that nickel-iron occurs as irregular patches and not as veins. The meteorite is most probably a chondrite, but the determination will remain doubtful until the specimen is cut."

Donations.

14. During the year collections of rocks, minerals and fossils were given to the following institutions :—

(1) Prince of Wales' College, Jammu ;

(2) Metropolitan College, Calcutta.

Additions to the Collections.

15. The only foreign specimens added to the collections during the year were :—

(1) australites from Australia, presented by Sir Thomas H. Holland, K.C.I.E., F.R.S. ;

(2) brown phlogopite, showing biaxial absorption figure presented by Sir Thomas H. Holland, K.C.I.E., F.R.S.;

(3) turquoise, said to come from Tibet.

Of the Indian specimens added to the collections the following deserve mention :—

(1) pitchblende from the Singar Mines, Kodarma, Gaya, presented by Mr. H. Harris ;

(2) crystals of aquamarine presented by the Kashmir Durbar ;

(3) native copper on calcite in weathered trap, from Kamshet, G. I. P. Ry., presented by Messrs. Pauling & Co. ;

(4) stibnite, from a locality 10½ miles north-north east of Chitaldrug, Mysore, presented by Mr. A. M. Smith ;

(5) molybdenite and molybdite in gneiss, from a locality 5 miles north of Palni, Madura district, presented by Mr. R. H. A. Johnston ;

(6) monazite from pegmatite at Yedur village near Bangalore, presented by Mr. V. S. Sambasiva Iyer;

(7) a tantalo-niobate and silicate of uranyl, iron and the rare earths, presented by the Director of Industries, Madras;

(8) a titano-niobate of uranyl and the rare earths, probably closely allied to euxenite, from Eranial taluq, South Travancore, presented by Mr. E. Masillamani.

Re-arrangement of Fossil Gallery.

16. The re-arrangement of the Fossil Gallery has been carried on uninterruptedly throughout the year. With the exception of the Upper Cretaceous and Tertiary invertebrate specimens, all the fossil collections other than types have now been stored in order in the drawers beneath the show-cases. A card-catalogue showing the contents of each drawer has been prepared. Half of the gallery has now been opened to the public.

Mineral Gallery.

17. In the Mineral Gallery, the main mineral collection has been overhauled, and the specimens assembled and placed in consecutive order as they occur in the register.

MINERALOGY.

18. Several rare minerals received from Mr. E. Masillamani, State Geologist, Travancore, were partially examined in the laboratory during the year. The most important of these are—

(1) a tantalo-niobate and silicate of uranyl, iron and the rare earths,

(2) a titano-niobate of uranyl and the rare earths, and

(3) a perfect cubic crystal of thorianite.

The first of these minerals, which was found 5 miles to the west of Vayampati, Kadavur Zemindary, Trichinopoly district, has the following composition :—

SiO_2 . .	9·80
Nb_2O_5 and Ta_2O_5	41·30
*R_2O_3 . .	5·60
UO_3 . .	27·06
FeO . .	9·72
H_2O . .	5·90
	99·38

* R = the rare earths, cerium, &c.

The mineral is probably hatchettolite or endeiolite. The second mineral, which is a titano-niobate of uranyl and the rare earths, and is probably closely allied to euxenite, was found in Erania taluq, South Travancore.

The specimen of thorianite, which was also received from Mr. Masillamani, was so small, and such a perfect crystal, that there was some hesitation in breaking off a part for analysis, but as, without this, its determination would have been merely conjectural, half the crystal was sacrificed for the purpose. A partial analysis gave the following composition :—

Rare earth oxides	2·92
ThO_2	32·27
U_3O_8	39·86
Fe_2O_3	11·10
Al_2O_3	1·12
Ca O	Trace.

The percentage of uranium oxide is unusually high for thorianite.

The above three minerals have so far been only partially investigated, but it is hoped to carry out further researches in regard to them as soon as an officer is in a position to spare time from the more pressing calls for investigations dealing with minerals urgently required for munitions.

PALÆONTOLOGY.

19. The publication of Mr. Vredenburg's results of his study of the Tertiary fauna of north-western India has again been retarded owing to various causes. The following notes on the subject have been submitted to me by Mr. Vredenburg :—

"Much delay has been caused, firstly, owing to certain corrections that were found necessary both in the published and in the unpublished portions of the "Fauna of the Ranikot Series" in Vol. III of New Series of the *Palæontologia Indica*; secondly, owing to the necessity for numerous amendments to Dr. Noetling's monographs on the Tertiary Fauna of Burma, affecting directly the work that is being done on the fauna of north-western India; thirdly, owing to the re-discovery of certain collections, formerly in the

possession of the Asiatic Society of Bengal, which were obtained by Blagrave in 1845 or 1846 from the same localities as those from which the same explorer had collected in 1811-15, and were presented to the Geological Society of London by whom, a few years later, they were sent to d'Archiac for study; containing as it does, genuine duplicates ("topotypes"), sometimes extraordinarily numerous, of many of d'Archiac's types, this collection has enabled me finally to clear up a number of points that had still remained doubtful, even after the examination of d'Archiac's original types now preserved at the British Museum. Since the publication of d'Archiac's monograph there has been so much confusion in the descriptions of the Tertiary faunas of India that it is now necessary to exercise the utmost caution before issuing any further publication on the subject.

"As regards the fauna of the Ranikot, the authors have experienced the same difficulty as many other palæontologists in attempting to identify the species illustrated in d'Archiac and Haime's monograph. It has been found that the synonymy clashes with that of the post-eocene more seriously than had been suspected, thus necessitating a very careful re-examination of most of the Ranikot species. The possibility of further confusion is obviated now that the post-eocene specimens in the collections of the Geological Survey have been identified by direct comparison with d'Archiac's types, and therefore constitute a safe basis for eliminating from the descriptions of the Lower Tertiary fossils all identifications with species now known for certain to be of post-eocene age. Other errors have also crept into the Ranikot monograph, and it has been necessary to revise it entirely, entailing thereby an enormous amount of labour, the time for which has encroached considerably upon that devoted to the post-eocene fauna.

"With regard to the fossil fauna of Burma dealt with in Dr. Noetling's monographs describing the Tertiary fauna of that province, a considerable number of mollusca have been identified with species from western India. It is known indeed that there are many forms common to both faunas, but a critical examination of the specimens described in Dr. Noetling's monographs has shown that, with one exception, all the supposed cases of identity are founded on inaccurate determinations. It was therefore found necessary to re-examine the material upon which Dr. Noetling's monographs were based. This has also been supplemented by the

collections made by Sub-Assistant Sethu Rama Rau between 1913 and 1915.

"Regarding the circumstance mentioned above, that of the re-discovery of Blagrave's collection, the subject is so involved that it cannot be more than alluded to here, though it is of great interest. One point of special importance that is now well established is that d'Archiac was misinformed as to the origin of the Sind fossils that were forwarded to him for study. Instead of having been collected entirely by Vicary, as he was given to understand and as has been assumed ever since, they were almost all obtained by Blagrave, largely from localities that are not even mentioned in Vicary's description of the geology of Sind. This circumstance is at the root of all the confusion that affected d'Archiac's own work, and has ever since foiled every attempt that has been made at successfully studying the Tertiary faunas of India.

"From these various sources of confusion, it follows that, in order to arrive at reliable results with regard to the post-eocene Tertiary fauna of north-western India, it has been necessary to revise practically the whole Tertiary fauna of India.

"One result which, though to some extent a negative one, is worth mentioning, bears upon the origin of the present-day fauna of the Indo-Pacific region. In his description of the Tertiary fauna of Burma published in the *Palæontologia Indica*, Dr. Noetling has endeavoured to prove that the miocene fauna of India is largely derived from the eocene fauna of Europe, and the present-day fauna of the Pacific from the miocene fauna of India. This theory has been widely accredited, but is now found to be untenable, the data upon which it is based being partly erroneous and largely insufficient. The inaccuracies are partly in the form of inexact specific determinations, partly in that of erroneous references as to geological age. The material studied by Dr. Noetling was scanty as regards post-eocene forms, while the Indian eocene fauna was at that time practically unknown. It seems now well established that, throughout the Tertiary, the fauna of the Indo-Pacific region evolved mostly *in situ* and independently of that of the Atlantic and the Mediterranean. At certain periods of extensive marine transgression there have been exchanges between the faunas of the east and west, but without any wholesale migration either in one direction or the other."

ECONOMIC ENQUIRIES.

Antimony.

20. Mr. A. M. Heron records the discovery of stibnite near the head of the Nga Wun Chaung, a tributary of the Ke Chaung, in Mergui. The stibnite was found in a quartz reef six inches wide, on the left bank of the stream. Only a small quantity was observed, and it is possible that this may merely indicate an isolated pocket of ore.

Chromite.

21. During the summer, Dr. L. L. Fermor visited the chromite mines at and near Hindubagh in the Zhob valley, Baluchistan. The chromite was discovered by Mr. Vredenburg in 1902, the rocks in which it occurs being described as "intrusive gabbros and serpentines, frequently chrome-bearing." It was supposed that the chromite occurred originally in the gabbro, and that the latter rock had been converted by hydration into serpentine. The more detailed work that Dr. Fermor was in a position to carry out has now proved that this description of the petrological conditions is not strictly accurate, and that the prevailing rock is in reality enstatite-peridotite or saxonite, with occasional areas of peridotite free from enstatite (dunite). The saxonite, which is locally traversed by dykes of dolerite, is rarely found fresh, the olivine being nearly always at least partially converted into serpentine. In addition to olivine and enstatite, the saxonite always carries a certain amount of the chrome-spinel picotite. The presence of this mineral indicates, according to Dr. Fermor, a genetic connection between the saxonite and the deposits of chromite. The latter occur as bodies of ore of very variable shape and size among the masses of saxonite, with which they are sometimes in actual contact; more frequently they are separated from the saxonite by a shell of serpentine, which is usually free from enstatite, and often carries scattered grains of chromite rather than of picotite. The general conclusions to which Dr. Fermor was able to come are

(1) that the non-pyroxenic serpentine represents the final result of the alteration of the saxonite, in which the conversion of the enstatite, through bastite to serpentine, is complete; and

(2) that the saxonite is the true home of the chromite.

The latter deduction is confirmed by the fact that where Dr. Fermor found fresh dunite, no chromite deposits were located, although the dunite carried scattered grains of chromite. The fact that the shell of non-pyroxenic serpentine, associated with the ore-deposits, carries chromite rather than picotite, led Dr. Fermor to the conclusion that there was a larger amount of chromium in the portions of the original saxonite magma immediately adjoining the ore-bodies; in fact, he regards the chromite deposits as segregations from the saxonite magma.

Coal.

22. Dr. Fermor's services were lent during the field-seasons 1915-16 and 1916-17, to the Railway Board, in order to survey and report on the Bokaro-Ramgarh coalfield.

ENGINEERING QUESTIONS.

Chichali Pass Dam.

23. At the request of the Local Government, Dr. M. Stuart examined the Chichali pass between the Mianwali district (Punjab) and the Kohat district (North-West Frontier Province) with regard to its suitability as a site for a dam. The proposal was to build a dam at the narrowest part of the pass where it cuts through the nummulitic limestone, and where the practically vertical walls are 250 or 300 feet high and only 14½ feet apart. In this way it was hoped to store up the water in the adjacent comparatively small valleys to the north, occupied by soft Tertiary sandstones and clays, and thus to render possible the irrigation of an area estimated at 4,000 acres. Dr. Stuart reports that the nummulitic limestone is traversed by numerous transverse cracks and joints in the neighbourhood of the proposed site, and that the pass itself owes its origin to water, which, originally held up by the ridge, subsequently percolated through the cracks and joints and partly dissolved and partly eroded the present pass. The site was consequently condemned as unsuitable for the purpose in view.

Proposed dam across the Sutlej at Bhakra.

24. In view of the proposal to build a reservoir for irrigation purposes by constructing a dam across the Sutlej in the narrow gorge through which that river breaks into the Una Dun, and doubts having been expressed as to the suitability of the site on account of the alleged softness

of the rocks reported to belong to the Siwalik formation, the services of an officer of this Department were asked for with a view to the geological examination of the proposed site. The work was entrusted to Mr. Vredenburg, who reports that the sandstone at the gorge does not belong to the typical soft Siwalik rocks of the age of the strata of the Siwalik Hills proper, but to the much older Nahan stage. It is a massively bedded rock of great hardness, yielding a strong and durable building material which is largely quarried in the neighbourhood. Apart from the question of engineering difficulties, Mr. Vredenburg considers the geological formations favourable, the rock being sound and the strata dipping upstream.

Jharia Waterworks.

25. In consequence of a request made by the Deputy Commissioner of Manbhum for the services of an officer of the Geological Survey to report on the quantity of gneiss available locally for facing the dam being built at Topchanchi in connection with the Jharia Waterworks scheme, Mr. G. de P. Cotter visited the locality in March, 1916, and made the necessary investigations.

Molybdenite.

26. Further discoveries of molybdenite in the Madras Presidency were made in October, 1916, by Mr. R. H. A. Johnston, Assistant Director, Madras Surveys. The mineral occurs in an intensely hard granite in Rettiambadi Mitta, Madura district, at a short distance to the east of the small village of Karadikuttam. The locality was subsequently visited by Mr. E. Vredenburg, who undertook a few preliminary prospecting operations. The prospects, unfortunately, proved to be too poor to offer any hope of successful exploitation. In view of the importance of molybdenite at the present time, it was, however, decided to continue investigations in the neighbourhood, and Mr. H. Walker is now making a systematic examination of the area.

Potash Salts.

27. The search for potash salts in the Salt Range and in the hills to the west of the Indus was continued by Dr. M. Stuart, who examined the numerous outcrops in the Nilawan ravine in the Salt Range. In only one case was potash detected in any of the outcrops, the quantity present being insignificant. Two potash-

bearing seams, however, were demarcated in the Nurpur salt mine, and a small quantity of material carrying about 14 per cent. of K_2O has been mined from them by the Northern India Salt Revenue Department.

28. Potash was also detected in the Warcha salt mine in the Shahpur district, and further experimental work is being done there to establish the extent of the potash-bearing seam. Subsequently, the salt of Kalabagh (Mianwali district) was visited and traces of potash were detected, but no seam of any economic value was found. Thence the investigation was carried on through the Lunwan pass into the Kohat salt region, where work is still proceeding. Traces of potash were detected at Nundrukka in Kohat, where Dr. Stuart has found the salt exposed to be intermediate in character between the salt of Kohat and that of the Salt Range. No other signs of potash have been detected in the Kohat salt from Nandrukka to the frontier at Bahadur Khel. The result of the investigation is to indicate that the two great salt series found on either side of the Indus are really continuous, and that the differences of character in the different exposures are probably due to the fact that different horizons of salt are exposed; the deposits having crystallised out from an evaporating saline solution varying in composition from bottom to top. This, as Dr. Stuart points out, is well seen in the salt deposits of Stassfurt; and, though the Indian salt has suffered a good deal of alteration and metamorphism, Dr. Stuart believes that there are indications of the existence of zones more or less equivalent to those recognised at Stassfurt. The salt is altered, and has undergone a good deal of movement, in the Cis-Indus area, and the potash seams thicken and thin out and disappear abruptly, but all traces of original sedimentation or bedding do not seem to have been lost; whereas, in the Trans-Indus area, Dr. Stuart points that the salt has been intensely sheared and metamorphosed, and the foliation planes probably do not agree in any way with the original bedding. He is of opinion that the view that the deposits are Tertiary is not upheld; the overthrusting in the Kohat area, where the salt is generally overlain by nummulitic beds, being much greater than in the Cis-Indus area, where it is generally overlain by Cambrian beds. The Kohat salt and included clay contains sulphide of iron, and Dr. Stuart has found gypsum in process of formation at the present day where calcareous alluvium washes on to the salt beds; he believes that

the Kohat salt owes its grey colour to the iron being present as sulphide, and that the Kohat gypsum, which always overlies the salt, owes its formation to the oxidation of the sulphide in the salt and included clays; this results in the production of sulphuric acid, which reacts with adjacent calcareous matter to form gypsum. Gypsum may have originated in this way at any period; a certain amount is undoubtedly being formed at the present day.

Sulphur.

29. At the request of the Government of the Punjab, Dr. M. Stuart was instructed to visit the Nammal gorge in the Mianwali district, where various minerals, such as mica, sulphur, iron, coal and petroleum, were said to occur. Dr. Stuart's investigations prove that no mineral deposits of economic value are found in the gorge. Small quantities of selenite, iron-stained efflorescent alum, carbonised plant remains and some impure hematite were observed. Most of these had already been referred to by Wynne. The selenite and stained alum were presumably responsible for the alleged occurrence of mica and sulphur, and the carbonised plant remains for that of coal. Dr. Stuart found no traces of petroleum, but a ferruginous film on the surface of a small sulphurous spring was probably responsible for the report of the occurrence of oil. The sulphur springs contain no appreciable quantity of sulphur. Dr. Stuart has suggested, however, that it might be possible to undertake the local manufacture of calcium carbide should the proposed hydraulic power scheme now under consideration for other purposes be ultimately carried out.

Tungsten.

30. Mr. J. C. Brown continued his work in connection with the wolfram mines in Tavoy and was joined in February by Mr. A. M. Heron. Both these officers worked with great assiduity and gave valuable assistance to the administrative officers employed by the Local Government. Sub-Assistants S. Sethu Rama Rau and M. Vinayak Rao were again attached to the party, and Mr. Brown reports favourably on their work. They were engaged chiefly in geological mapping. The energetic measures taken by the Government of Burma, with the assistance of the Geological Survey party, have resulted in a very notable increase of the output

of wolfram, which rose from 2,115 tons in 1915 to 3,034 tons. It is hoped that there will be a considerable increase over the latter figure in the year 1917. Large areas in Tavoy have now been geologically surveyed, chiefly by Mr. Heron and Sub-Assistants Sethu Rama Rau and Vinayak Rao. A certain amount of ground was also surveyed by Mr. Brown, whose services, however, were urgently required throughout the year in connection with the development of the mines, and could not, therefore, be spared for regular field-work.

31. A small laboratory was established at Tavoy early in the year, partly with a view to preventing the unauthorised export of tin concentrates rich in wolfram, and partly with a view to assisting the local mining community. The Assistant Curator was sent from the Geological Survey laboratory in Calcutta and took charge of the chemical work. The total number of assays asked for during the year, however, has been insignificant. The members of the local mining community have only availed themselves to a very small extent of the opportunities offered by the presence of the laboratory, and its retention in Tavoy is of very doubtful utility.

GEOLOGICAL SURVEYS.

Bombay, Central India & Rajputana.

32. The party consisted of Mr. C. S. Middlemiss, C.I.E., and Messrs. A. M. Heron and N. D. Daru.

Mr. C. S. Middlemiss.

Mr. Middlemiss was at headquarters during the greater part of the year, and officiated as Director from October 2nd to November 12th. In the early part of the year he spent a short period in camp completing his survey of Idar State and inspecting the work of Mr. Heron.

Mr. A. M. Heron.

33. During the month of January and the first week of February, Mr. Heron continued his survey of the Ajmer and Beawar tahsils of Ajmer-Merwara. The area is covered chiefly by rocks of the Aravalli system, which Mr. Heron found to consist largely of calc-gneiss and impure crystalline limestone penetrated by a few sill-like masses of granite and innumerable veins of amphibolite and pegmatite. In the north-eastern part of the area, near Sarsari, there is a remarkable development of massive garnet-rock occurring in bands which are

occasionally as much as 12 feet wide. Above the calc-gneiss is a great thickness of hornblende-schist and banded hornblende-epidote gneiss, very regularly foliated and lying in broad simple folds. Intercalated in these are elongated and discontinuous lenticles of quartzite, mica-schist and crystalline limestone of all sizes, which presumably either represent aqueous beds included in a mass of extruded lavas and subsequently metamorphosed with mutual interaction, or are the remains of a sedimentary series into which the hornblende rocks have been intruded to such an extent as almost to obliterate it. On the west, the Aravalli rocks underlie a band of arkose, which Mr. Heron tentatively regards as the base of the Delhi system. On the east, the base of that system is perfectly definite and conspicuous; a short distance above it, and parallel to it, a thrust fault was traced for several miles cutting out most of the subsidiary and highly compressed syncline in the broad band of micaceous (Delhi) limestones which forms the eastern side of the Beawar valley.

34. In February, Mr. Heron's services were required for urgent work in connection with the increase of the production of wolfram in Burma, and he was, therefore, compelled to close his work in Rajputana for the present (see pp. 16, 19).

Mr. N. D. Daru.

35. Mr. Daru's services were re-transferred to the Geological Survey from the Madras Education Department in June. He was then re-posted to the party to which he had formerly belonged, and was deputed for the field-season to Western Rajputana to complete the survey of an unmapped portion of Jaisalmer State. This work, unfortunately, could only be undertaken on a small scale, since no topographical maps larger than $1''=16$ m. were available. The area remaining unsurveyed, however, was small, and the work was undertaken mainly with the object of completing the geological map of India on the scale of $1''=32$ m., on which a part of this area remained a blank. Mr. Daru left for the field on December 1st and spent a considerable part of that month in examining typical sections of the rocks of Western Rajputana in Jodhpur State. After visiting Jodhpur, he proceeded to Phalodi, whence he marched *viâ* Pokaran, with a view to examining the famous Pokaran boulder-bed, through Lathi to Jaisalmer. During the latter part of the month, he examined the rocks round Jaisalmer, and records the discovery of numerous striations and groovings on certain limestones in that

neighbourhood. Mr. Daru is inclined to regard these striated limestones as a striated pavement produced by glacial action. The striations, however, are more probably due to wind sculpture.

Burma.

36. The Burma party consisted of Messrs. H. Walker, J. C. Brown, A. M. Heron, and Sub-Assistants S. Sethu Rama Rau and M. Vinayak Rao.

Mr. H. Walker.

37. With the exception of Mr. Walker, the whole party was engaged in work connected with the wolfram industry of Tavoy and Mergui. Mr. Walker spent the greater part of the season in visiting, and reporting on, wolfram-bearing areas, including Mawchi in Bawlake State, various localities in the Thaton district and, subsequently, localities in the Yengan State, Southern Shan States. In addition to this work, Mr. Walker visited the Thayetmyo district at the request of the Local Government and demarcated the boundaries of the new Tagaing oil-field. He then proceeded to the Myaing township of the Pakokku district to resume the systematic geological survey where it had been left by Mr. Cotter.

Messrs. J. C. Brown, A. M. Heron, S. Sethu Rama Rau and M. Vinayak Rao.

38. During the greater part of the year, Messrs. Brown and Heron were employed in examining and reporting on wolfram mines in Tavoy and Mergui (*supra* p. 16). After the close of the monsoon, however, when it became possible to resume geological field-work, the whole party, with the exception of Mr. Brown, took up actively the geological survey of the Tavoy district. In spite of the great difficulties to be contended with owing to the extremely wild nature of the country and the lack of inhabitants, a large area of new country has been surveyed. The rocks met with consist almost entirely of granite and the sedimentary beds of the Mergui series. In the southern part of the district, Mr. Heron was able to distinguish three distinct types of granite, two of which had not previously been recorded in Tavoy. The three types are :—

(*a*) coarse to medium-grained biotite granite with white felspar sometimes porphyritic. This is the chief constituent of the great mass of mountains forming the back-bone of the Tavoy district and running through Hermingyi, Wagon, Paungdaw, Pedaung and Bok raung

(*b*) a remarkable porphyritic granite containing large idiomorphic phenocrysts of zoned pink felspar in a fine-grained groundmass, the ferro-magnesian constituent of which appears to be hornblende. This granite forms large dykes in the Mergui series, but it is believed to be associated with type (*a*) in larger masses;

(*c*) a tourmaline-pegmatite, occurring chiefly in veins, but also in one instance appearing to form large masses. The tourmaline is occasionally replaced by muscovite, but these two minerals have not been observed together in any quantity.

Central Provinces.

39. Owing to the absence of Dr. L. L. Fermor on special duty under the Railway Board and of Mr. H. Walker in Burma, the only work carried out in the Central Provinces during the year was that of Mr. K. A. K. Hallowes, who was deputed to examine the Makrai State with a view to the possible discovery of minerals of economic value. Some little time ago, the ruler of Makrai forwarded a request to the Geological Survey through the Central Provinces Administration that a mineral survey of his State should be undertaken. This was begun in the field-season of 1915-16 by Sub-Assistant M. Vinayak Rao; the work, however, had to be abandoned almost immediately owing to Mr. Vinayak Rao's services being required for urgent work elsewhere; opportunity for its resumption was offered at the beginning of the season 1916-17, and during November and December it was completed. Mr. Hallowes reports that the whole State consists of alluvium in the north and Deccan Trap in the south, with no trace of any minerals of economic value. On the completion of his work in Makrai Mr. Hallowes was deputed to fill in certain alluvial areas left unmapped by the late Mr. R. C. Burton in the districts of Balaghat and Bhandara.

Mr. K. A. K. Hallowes.

Nizam's Dominions.

40. In the General Report for last year it was stated that it had been decided to carry out a rapid traverse in order to determine broadly the distribution of the Deccan Trap and crystalline rocks respectively along the eastern boundary of the Nizam's Dominions in longitude 77°-79°

Mr. K. A. K. Hallowes.

and latitude 18°-19°. The object of this traverse was to complete that portion of the geological map of India on the scale of 1″=32 m. Mr. Hallowes was detailed to make the traverse and completed the work at the end of April. Mr. Hallowes reports that the rocks met with during the traverse consist of—

(3) Deccan Trap, with Intertrappean beds,
(2) Lameta limestone, and
(1) granitoid gneiss of Archæan age.

The trap shows no unusual characters, the flows being generally horizontal and having occasionally a very slight local dip. Layers of glauconitic green earth with heulandite occur between the flows. The basal flow is said by Mr. Hallowes to be slightly vesicular and to contain geodes of quartz, chalcedony, opal, chlorophæite and calcite. The trap itself is a dense black basalt without olivine; it is said to be frequently porphyritic, with phenocrysts of resin-yellow felspar. Red bole is occasionally found at the base of the trap.

Intertrappean beds are said to be rare and poorly exposed, the only sign of their presence being occasional loose boulders of chert scattered over the surface of the ground. One of these fragments yielded fossils which have been determined by Mr. Vredenburg as *Paludina deccanensis* Sow. and *Limnæa subulata* Sow.

True Lameta limestone was met with at only one locality, Siddapur (18° 20′ : 77° 38′). Mr. Hallowes states, however, that he occasionally found a white calcareous rock at the base of the trap. This rock he regards not as true Lameta limestone, but as a calcified gneiss, similar no doubt to the rocks which Dr. Fermor and Mr. Burton found in the Central Provinces to be metamorphosed members of the Archæan group, although originally ascribed to the Lameta series.

41. Mr. Hallowes records a considerable number of varieties of gneiss, including biotite-gneiss, hornblende-gneiss, epidote-gneiss, and numerous other local modifications such as might be expected to occur in a broad area of granitic rocks. On the whole, the typical rock, which is said to be an orthogneiss, may be described broadly as porphyritic pink gneissose granite containing chiefly quartz, orthoclase, oligoclase, mica, chlorite and hornblende; the commonest form is said to be chloritized biotite-granite-gneiss. Mr. Hallowes regards the gneiss as similar to those of Hosur, Bundelkhand and Singhbhum. He further states that foliation is imper-

ceptible in hand-specimens, and can only be noticed on exposed surfaces of considerable area. It would thus be more correct to describe the rock consistently as granite rather than as gneiss. Mr. Hallowes further states that it is traversed by veins of aplite composed of quartz, felspar and garnet without any trace of mica. It is also pierced by narrow dykes of augite-diorite, with micro-pegmatite, and by dykes of dolerite, which latter Mr. Hallowes believes to be of Cuddapah age. Dykes of the augite-diorite are recorded from Anuntasagam (17° 33′ : 78° 1′) and of the dolerite from Sedosphor (18° 35′ : 77° 43′) and Singapuram (18° 8′ : 77° 48′).

A REVISED CLASSIFICATION OF THE GONDWANA SYSTEM. BY G. DE P. COTTER, B.A., F.G.S., *Assistant Superintendent, Geological Survey of India.*[1]

Introduction.

The Geological Survey's collection of fossil plants, which is exhibited in the show-cases of the Fossil Gallery of the Indian Museum, had not been overhauled for many years, many of the labels and identifications dating from the days of Dr. O. Feistmantel, who retired in 1885. It has now been found necessary to check and re-arrange our exhibits, and in several cases to make certain changes in the generic and specific names, in accordance with the recent work of Messrs. Zeiller and Seward. A sub-division of the Gondwana System into palæobotanical series and stages has been attempted, and it is necessary to explain this revised classification in a brief note.

In tabular form, the classification is as follows :—

UPPER GONDWANA.	Umia-Jabalpur Series.	Umia Stage	Lower Cretaceous.
		Jabalpur Stage	Middle or Upper Oolite.
	Mahadeva Series	Kota Stage	Lower Oolite and Upper Lias.
		Rajmahal Stage	Liassic.
LOWER GONDWANA.	Panchet Series	Parsora Stage and Maleri Stage.	Upper Trias and Rhætic.
		Panchet Stage	Lower Trias.
	Damuda Series	Raniganj Stage	Upper Permian.
		Ironstone Shale Stage.	Middle Permian.
		Barakar Stage	Lower Permian.
	Talchir Series	Karharbari Stage	Upper Carboniferous.
		Talchir Stage	Upper Carboniferous.

[1] Paper read at the 4th meeting of the Indian Science Congress held at Bangalore (January 1917).

The following table shows the stages of the Gondwana System and their leading species of plants and animals :—

STAGE NAMES.	CHIEF LOCALITIES.	LEADING SPECIES.
Umia Stage . .	Kachh, Kathiawar .	*Cladophlebis denticulata, Ptilophyllum cutchense, P. brachyphyllum, Otozamites contiguus, Williamsonia blanfordi, Palissya bhoojoorensis, etc.*
Jabalpur Stage .	Near Jabalpur, Narbada Valley, Narha, Kachh ?	*Cladophlebis lobifolia, C. denticulata, Podozamites lanceolatus, Otozamites hislopi, O. gracilis, Pterophyllum nerbuddaicum, Williamsonia* cf. *gigas, Palissya jabalpurensis, etc.*
Kota Stage . .	Kota, Ragavapuram, Vemaveram, Sripermatur, Utatur.	*Ptilophyllum acutifolium, Palissya conferta, P. jabalpurensis, Otozamites abbreviatus, Taxites tenerrimus, Araucarites cutchensis, Tæniopteris spathulata, Cladophlebis denticulata, Thinnfeldia subtrigona.*
Rajmahal Stage. .	Ramahal Hills, Golapilli, Budavada, Athgarh.	*Thinnfeldia salicifolia, Danæopsis rajmahalensis, Pterophyllum princeps, P. rajmahalense, Tæniopteris lata, Williamsonia microps, Palissya indica, etc.*
Parsora Stage . .	Parsora, South Rewah, Ramkola Coal-field ?, Daigaon, S. Rewah ?	*Thinnfeldia odontopteroides, Danæopsis hughesi, Cordaites hislopi ?, Cladophlebis denticulata ?, Glossopteris indica.*
Maleri Stage . .	Maleri, Wardha Valley, Denwa, Narbada Valley, Tiki, South Rewah.	No plant remains, *Hyperodapedon huxleyi, Belodon, Parasuchus, Massospondylus, Ceratodus, Mastodonsaurus* and other labyrinthodont remains.
Panchet Stage . .	Raniganj, Bokaro, Almod, Pachmarhi ?, Mangli in Wardha Valley.	*Schizoneura gondwanensis, Glossopteris indica, G. damudica, Pecopteris concinna, Gonioglyptus, Pachygonia, Dicynodon, Epicampodon, ?Brachyops.*
Raniganj Stage .	Raniganj, Jherria, Bokaro, etc. Bijori, Narbada Valley; Kamthi, Silewada, etc., near Nagpur; Hingir near Sambalpur,? South Rewah.	*Schizoneura gondwanensis, Actinopteris ? bengalensis, Sphenophyllum speciosum, Gangamopteris hughesi. G. whittiana, Glossopteris indica, G. ingens, G. divergens, G. stricta, G. conspicua, G. formosa, Cladophlebis Roylei, Paleovittaria kurzi, Voltzia heterophylla, Rhipidopsis densinervis, Sphenopteris polymorpha, Gondwanosaurus*
Ironstone Shale Stage	Raniganj, Jherria, Bokaro, etc., Motur in Narbada Valley.	*Gangamopteris cyclopteroides, Glossopteris ampla, G. indica G. retifera, G. conspicua, Cordaites hislopi, Sphenopteris hughesi.*
Barakar Stage . .	Bengal Coal-fields, Rajmahal Hills, South Rewah, Narbada Valley, Godavari Valley.	*Schizoneura gondwanensis, Phyllotheca griesbachi, Sphenophyllum speciosum, Glossopteris intermittensa, G. ampla, Tæniopteris danæoides, T. feddeni, Sphenopteris polymorpha, Gangamopteris cyclopteroides, Cordaites hislopi.*
Karharbari Stage .	Giridih, Mohpani, Daltonganj, Hutar, South Rewah ?	*Schizoneura wardi, Gangamopteris cyclopteroides, G. buriadica, Glossopteris indica, G. longicaulis, G. decipiens, Cordaites hislopi, Voltzia heterophylla, Ottokaria bengalensis.*
Talchir Stage . .	Bengal Coal-fields, Rajmahal Hills, South Rewah, Narbada Valley, Salt Range, Bap, Pokaran, Godavari Valley, etc.	*Gangamopteris cyclopteroides, G. angustifolia Glossopteris communis, Cordaites hislopi.*

The main differences between this scheme and that employed in the *Manual of the Geology of India*, 2nd edition, 1893, are as follows :—

(1) the separation of the Maleri from the Kota Stage, and the removal of the former to the Upper Trias;

(2) the introduction of a new stage name for some beds of Rhætic age near Parsora and Daigaon villages in South Rewah. These beds were formerly known as "Transitional Beds" or Middle Gondwana (Feistmantel: Fossil Flora of the South Rewah Gondwana Basin, *Pal. Ind.*, ser. XII, vol. IV, pt. 1, pages 5, 6). The new name is derived from the village of Parsora, where these Rhætic species are found;

(3) the Umia Stage of Kachh is regarded as Lower Cretaceous rather than Upper Oolite; in the *Manual of the Geology of India* it is regarded as of Upper Oolite age.

I shall now discuss these points in order.

Age of the Maleri Stage.

Although in the *Manual* it is acknowledged that the Kota Stage overlies the Maleri, yet both are grouped as of post-Rajmahal and of Lower Oolite age. W. T. Blanford in 1878 had already pointed out the Triassic affinities of the Maleri reptiles, and the Jurassic affinities of the Kota fishes, while King (*Mem. Geol. Surv. India*, XVIII, p. 268) had shown that the two stages were separable on lithologica and stratigraphical grounds. In a later paper Prof. Koken also points out that the reptilian remains of the Maleri Stage indicate an age not younger than upper Keuper.[1]

The chief reasons for placing the Maleri Stage in the Upper Trias are as follow :—

The presence of undoubted labyrinthodont remains at Denwa, Maleri, and Tiki in South Rewah. At Denwa *Mastodonsaurus indicus*[2] is found; at Tiki a fragment of a labyrinthodont jaw and several fragments of sculptured cranial bones were found. Lydekker regards these fragments as showing a close relationship to

[1] Koken: Indisches Perm und die permische Eiszeit. *Neues Jahrbuch fur Mineralogie, Geologie und Paleontologie, Festband,* 1907, p. 498.

[2] This specimen is identified as *Mastodonsaurus sp. indet.* in *Pal. Ind.*, ser. IV, pt. 5, p. 30, but the specific name is given in the British Museum *Catalogue of Fossil Reptilia and Amphibia,* pt. IV, p. 145.

Metoposaurus,[1] but the teeth are considerably larger than those of the German species *Metoposaurus diagnosticus*. The difference in the size of the teeth, although pronounced, is less than would at first sight appear, if we remember that the teeth of the lower jaw of this genus, according to Fraas,[2] are distinctly larger than those of the maxilla. The jaw fragment figured in *Palæontologia Indica* (*loc. cit.*) by Lydekker is identified as part of the right maxilla, but in the British Museum Catalogue, it is called a jaw. This possibly indicates a change of opinion on Lydekker's part. It appears to me that the fragment in question is undoubtedly part of the lower jaw. It consists of two bones, as is evident from the two medullary cavities seen in cross-section; these bones are probably the dentary and angular. I also found at Tiki a fragment of a similar jaw, and several cranial fragments. At Maleri, various sculptured bones have been found; the sculpturing is so similar to that of the Tiki specimens, that it seems probable that they are fragments of the same species.

The order *Labyrinthodontia*, makes its first appearance in the Carboniferous, and, we have good reason to believe, died out in the Rhætic. A very useful list of the described species of Fossil Amphibia has recently been published by R. L. Moodie,[3] in which the horizon of each species is given. Another list of the South African Reptilia and Amphibia is given by R. Broom.[4] From these two lists I have found only one example of a labyrinthodont surviving beyond the Rhætic. This is the species *Rhinosaurus jasikovii* from the Lower Oolite of Simbirsk in Russia. The species was described in 1847, and its late age has been remarked on by Lydekker.[5] Since it is the only known instance of the survival of this order into the Jurassic, and since there is no known example of a labyrinthodont in the Lias, one is inclined to wonder whether some mistake was not made in determining its horizon.

The relationships of the Indian labyrinthodonts above mentioned indicate an Upper Triassic age. *Mastodonsaurus* in Europe ranges from Upper Muschelkalk to Keuper, and is found in the Hawkesbury Beds of Australia. *Metoposaurus* is of like age. The

[1] B. M. Cat. of Foss. Reptiles and Amphibia, IV, p. 154.

[2] E. Fraa : Die Labyrinthodonten der Schwabischen Trias: *Palæontographica*, XXXVI, p. 150.

[3] *Kansas Univ. Science Bulletin*, vol. IX, p. 13 (1914).

[4] *Ann. of the South African Museum*, VII (1913), p. 285.

[5] *Pal. Ind.*, ser. IV, vol. I, pt. 4, p. 13.

species *Hyperodapedon huxlei* is found both at Tiki and at Maleri; the genus is found in the Keuper of Europe. The crocodilian, *Belodon,* also found at Tiki, has Triassic affinities, while another crocodilian, *Parasuchus,* found at Maleri, belongs to a Triassic sub-order. At Maleri, three species of the dipnoan fish *Ceratodus* occur. *Ceratodus* in South Africa ranges from the *Cynognathus* zone of the Beaufort Beds (Upper Trias) to the Red Beds of the Stormberg Series (Lower Jurassic), and is found in the Trias and Jurassic of Europe. At Tiki a species of *Unio* is found. Occurrences of *Unio* in rocks earlier than the Oolite are rare, but this is probably due to imperfect collection. E. Haug [1] states that the *Unionidæ* begin in the Jurassic, but of course he, with others of the French school, includes the Rhætic in the Jurassic. *Unio,* however, is found in the Hawkesbury Beds of Australia, and there is also a doubtful instance of its occurrence in the Trias of America [2]; the occurrence, therefore, of *Unio* at Tiki is no evidence in favour of a later age than Upper Trias. At Tiki also is found a dinosaur, referred at first doubtfully by Lydekker to the genus *Thecodontosaurus,*[3] but afterwards identified with the South African *Massospondylus,*[4] a genus which is found in the Red Beds and Cave Sandstone of the Stormberg Series of South Africa. Broom [5] regards the Cave Sandstone as Lower Jurassic, and probably the Red Beds as well. Unfortunately the Molteno Beds, which appear to be Rhætic in age, and which form the base of the Stormberg Series, immediately below the Red Beds, have yielded no fossil reptiles nor amphibia. We cannot therefore base any argument upon the absence of *Massospondylus* from the Molteno Beds, which, according to Broom, are the uppermost members of the South African Trias, and are probably of Rhætic age.

The whole of the fossil evidence from the Maleri Stage points to an Upper Triassic, and possibly a Rhætic, age; but it might also be older than Rhætic, *i.e.*, Keuper. The age of the Kota deposits is not in dispute. It is generally admitted that the flora is later than that of the Rajmahal Stage, but older than that of Jabalpur. The fish remains of Kota

The Kota Stage.

[1] *Traité de Géologie,* p. 935.
[2] Süssmilch: *Geology of New South Wales,* p. 113.
Fischer: *Manuel de Conchyliologie,* p. 999.
[3] *Pal. Ind.,* ser. IV, vol. I, pt. 5, pp. 28, 29.
[4] *Rec. Geol. Surv. Ind.,* XXI, p. 146.
[5] *Loc. cit*; see also *Ann. South Afr. Mus.,* VII, p. 307.

point to an age not earlier than Lias. The marine fossils found together with a Kota flora at Ragavapuram (*Macrocephalites*, *Trigonia interlævigata*) point to a Lower Oolite age, and this is the age given in the *Manual.* There appears to be no reason for altering this view.

The Panchet Stage.

The Panchet Stage has been placed in the Lower Trias, and there appears to be good reason for this view. The dicynodont *Ptychosiagum orientale* is very probably referable to the genus *Lystrosaurus*, a genus which characterises the basal beds of the South African Trias (*Lystrosaurus* zone). Prof. Koken [1] argues that the presence of the dinosaurian *Epicampodon* is indicative of an Upper Triassic age, and he has therefore placed the Panchets in the Upper Trias. But this genus, although related to the Upper Triassic genera *Zanclodon* and *Thecodontosaurus*, nevertheless presents features which may permit us to suppose that it is an older form, since the animal was evidently a particularly small type, and the marginal serrations of its teeth appear to be somewhat rudimentary and imperfectly developed.

The flora of the Panchet Stage is scanty and does not enable us to form an opinion of its relationships to the Parsora and Maleri stages. From the list given in the *Manual of the Geology of India*, 2nd ed., p. 171, we must remove the species *Dicröidium* (*Thinnfeldia*) *odontopteroides*, which is found only in two localities, one of which is Parsora in South Rewah, and the other the Ramkola-Tatapani coal-field. Probably both these localities represent higher horizons than the Panchet stage of the Raniganj coal-field. The Raniganj coal-field is the type area of the Panchet stage, and comprises that portion mapped by W. T. Blanford as Lower Panchet. This restricted use of the term is officially adopted in the *Manual* (p. 170), and this is the sense in which it is used in this paper.

From the foregoing it will appear that we have reasonable grounds for regarding the Maleri as distinctly newer than the Panchet, and for placing the former in the Upper, and the latter in the Lower, Trias.

The Damuda Series.

The Damuda Series has been regarded by the Geological Survey in all recent publications as Permian or Permo-Carboniferous. Koken erroneously places the Talchir Stage in the Lower Permian,[2] and, in consequence he is

[1] *op. cit.*, p. 499.
[2] *op. cit*, p. 483.

led into the further error of raising the Damuda Series into the Trias. The stratigraphical position of the Talchir Boulder-bed in the Salt Range indicates that the Talchir Stage is not Permian, but Upper Carboniferous.[1] In Kashmir, the Agglomeratic Slate, which probably represents the Talchir,[2] extends to the Upper Carboniferous, the upper division or Nagmarg Beds being Uralian,[3] while the Gangamopteris Beds above the Agglomeratic Slate are Lower Permian according to Diener, and consequently would be homotaxial with the Barakar Stage.[4]

The flora of the Damuda Series is essentially Palæozoic, and contains such genera as *Sphenophyllum, Phyllotheca* and *Gangamopteris*. Two amphibians are attributed to the Raniganj Stage of the Damudas, *viz., Gondwanosaurus* and *Brachyops*. The former is allied to *Archægosaurus*, a genus which is found in the *Gangamopteris* Beds of Kashmir,[5] and occurs at Bijori in the Narbada Valley in company with *Sphenophyllum* and *Gangamopteris* and other plants which indicate a Raniganj horizon. It is obviously of Permian and not of Triassic affinities. *Brachyops laticeps* comes from a village named Mangli, 10 miles north of Warora in the Wardha Valley, and may possibly be of Panchet age; there is at least no reason why we should insist on including it in the Damuda Series. *Brachyops* is supposed to be closely allied to the genus *Micropholis* which characterises the *Procolophon* zone (Lower Trias) of the Beaufort Beds of South Africa. One might therefore doubtfully place the Mangli beds in the Trias. In any case it must not be forgotten that the isolated occurrence of an amphibian in an isolated area with very few other fossils, and in beds of doubtful age, can be of no possible help to us in unravelling the age of the Damuda flora. There is therefore no reason to accept Koken's view, and I adhere to the opinion expressed in the *Manual*.

The Parsora Stage.

The name Parsora stage is now introduced for the first time to represent the deposits of Rhætic age found in South Rewah, and possibly in the Ramkola-Tatapani coalfield. These beds were described, as has been mentioned above, as Transitional Beds or Middle Gondwana by Feistmantel. The most important locality is the village of Parsora,

[1] See *Manual of the Geology of India*, 2nd ed., pp. 121, 167, 208.
[2] C. S. Middlemiss, *Rec. Geol. Surv. Ind.*, XL, p. 233.
[3] *Rec. Geol. Surv. Ind.*, XV, p. 135.
[4] *Pal. Ind.*, New Ser., V, mem. 2, p. 111.
[5] *Pal. Ind.*, New Ser., II mem. 2, p. 13.

where the following species occur :—*Danæopsis hughesi, Dicroidium odontopteroides*,[1] *Asplenium whitbyense* (=*Cladophlebis denticulata ?*) and *Cordaites hislopi*.[2] *Danæopsis hughesi* is found in the uppermost part of the Beaufort Beds of South Africa, and in the Rhætic of Tonkin and China.[3] *Dicroidium odontopteroides* is a well-known Rhætic species, a full account of which is given by Seward in a paper on the Fossil Plants of South Africa.[4] It is found in the Molteno Beds, the lowest division of the Stormberg Series, of South Africa; it is absent from Tonkin according to Zeiller,[5] but Seward[6] thinks that a specimen figured by Zeiller under the name of *Pecopteris sp.* may belong to this species.

In Australia it characterises a similar Rhætic horizon,[7] and is also found in the Rhætic of South America and parts of Europe.

The specimens of *Cordaites hislopi* from Parsora are isolated broken leaves. Zeiller records *Cordaites hislopi* from the Rhætic of Tonkin. Seward [8] suggests that the species *Phenicopsis elongatus* from the Stormberg Series of South Africa, which is also found in Australia may be identical with the isolated leaves from Tonkin, referred by Zeiller to *Cordaites*. The same identification would be possible for the fragmentary leaves from Parsora. Although *Glossopteris* has not been found at Parsora, it occurs in some exposures of rocks at the neighbouring village of Daigaon, which are probably of the same horizon. *Glossopteris* is also found in the Rhætic of Tonkin, but not in later beds.

Enough has been said to show the strong evidence in favour of regarding the Parsora plants as of Rhætic age. It appeared to me therefore, to be no easy matter to settle the relative ages of the Parsora and Maleri Stages. The geology of South Rewah, where the Parsora beds and the Tiki deposits both occur, was described by T. W. Hughes, in a paper published in the *Records* of the Geological Survey of India.[9] In this paper he identified

[1] The genus *Dicroidium* has recently been separated off from the genus *Thinnfeldia* by Gothan: see his monograph Ueber die Gattung *Thinnfeldia* Ettingshausen, *Abh. Naturh. Gesellsch. Nurnberg*, Bd. 19, III, and a postscript in Bd. 19 heft 4; see also E. Anteus: Die Gattungen *Thinnfeldia* Ett. und *Dicroidium* Goth., *Kungl. Svenska Vetensk. Acad.*, Handl., Bd. 51, No. 6 (1914).

[2] *Pal. Ind.*, ser. XII, vol. IV, pt. 1, p. 6.

[3] Seward: Fossil Plants, vol. II, p. 409.

[4] *Quart. Journ. Geol. Soc.*, LXIV, p. 90.

[5] R. Zeiller: Flore fossile des Gites de Charbon de Tonkin

[6] *op. cit.*, p. 94.

[7] Süssmilch: Geology of New South Wales, p. 120.

[8] *Ann. of the S. Afr. Mus.*, IV, p. 68.

[9] Vol. XIV, p 126.

the Tiki deposits on lithological and palæontological grounds with the Maleri deposits of the Pranhita-Godavari Valley, and the palæontology, as has been shown, corroborates this. Owing to the presence of *Thinnfeldia* and *Danæopsis* in the Parsora beds, Hughes supposed the latter to be of Rajmahal age, and calls them Mahadevas. In his paper, he places the Maleris of Tiki above the Parsora beds (" Mahadevas "), but does not seem very certain about it, and several passages in his paper show that he was in considerable doubt as to their mutual relationships. On p. 136 he says: " If we look at the map, the Mahadevas east of Banas appear to overlap the Maleris. This of course cannot be "; and again (p. 137): " These low-level Maleris form the base of the group. Above them are rocks alarmingly like the Mahadevas." As there seemed considerable doubt regarding the relative ages of the two stages, I visited South Rewah in October 1916, examining the country round Daigaon, Parsora, and to the north as far as Tiki. I collected several specimens of *Danæopsis hughesi* from Parsora, and of *Hyperodapedon huxlei*, reptilian teeth, labyrinthodont cranial sculptured bones and a labyrinthodont jaw fragment from Tiki. But I could not find any new species, nor any fresh palæontological evidence. I found that the beds at Parsora were practically horizontal; one could not say that there was a dip in any particular direction, although local warping was not uncommon. At Daigaon, there appeared to be a slight southerly dip, but this was probably local. The Bandogarh Hill to the north-west of Parsora showed horizontal strata. The same horizontality prevailed round Taripathar on the Son River and at Tiki, associated of course with gentle undulatory warping in no special direction. Owing to the heavy soil-cap, and infrequency of exposures, it was quite impossible to trace a bed from Parsora to Tiki, and I therefore could not decide the question one way or the other. It seems to me that there is no objection to supposing the Maleris of Tiki to be below the Parsora beds. If the beds were absolutely horizontal, the Maleris at Tiki being only about 1,200 ft. above sea-level, would undoubtedly be older than the Parsoras, which are two or three hundred feet higher in altitude. To suppose that the Maleris are newer than the Parsoras, we have to regard the Rewah Gondwana basin as a syncline, with the older beds around its margins and the newest beds in the middle. Yet the newest beds in the field, that is the beds around Chandia, which contain an undoubted

Jabalpur stage flora,[1] are situated, not in the middle of the basin, but on its south-western margin, a fact which would seem to show that the Parsora beds may also equally well be above the Maleris, and that the structure is not necessarily a simple syncline. Although I cannot make any decision on the point, I have tentatively placed the Parsora Stage above the Maleri Stage, and I regard the former as Rhætic, and the latter as either Keuper or Rhætic in age.

Before leaving the subject of the Parsora Stage, I may mention that when overhauling Hughes' specimens from South Rewah, I found specimens of *Danæopsis hughesi* from a new locality, namely the village of Barhuth, which is 10 miles N. W. by W. from Parsora.

The Umia Beds.

The last change introduced in this revised scheme is the removal of the Umia Stage of Kachh from the Jurassic to the Lower Cretaceous. The *Manual* (p. 207) notices the similarity of the fauna of the marine Umia beds, which underlie the plant beds, to that of the Uitenhage Series of South Africa. The reader is referred to two papers by F. L. Kitchin,[2] where a full discussion of the age of the Umia Stage will be found. Kitchin refers the Umia beds to the Lower Cretaceous, and this view is now, I believe, generally accepted.

[1] *Pal. Ind.*, ser. XII, vol. IV, pt. 1, pp. 3, 4.

[2] On the Genus *Trigonia*: *Pal. Ind.*, ser. IX, vol. III, pt. 2 (1903). The Invertebrate Fauna and Palæontological Relations of the Uitenhage Series *Ann. of the South Afr. Mus.*, VII, 1, (1913).

Table of Gondwanaland deposits.

EUROPE.	INDIA.		NEW SOUTH WALES.		VICTORIA.	TASMANIA.	QUEENSLAND.	SOUTH AFRICA.	ARGENTINA.	BRAZIL.
JURASSIC AND LOWER CRETACEOUS.	Umia Stage .	Mahadeva Series.	....		..	..	..	Uitenhage Series.	..	Sao Bento Series.
	Jabalpur Stage .		....		..	..	..	..	..	..
	Kota Stage .		....		..	..	..	..	..	..
	Rajmahal Stage		....		Bellarine Coals.	..	Ipswich Series.	Cave Sandstone. Red Beds .	..	..
TRIASSIC.	Parsora Stage .	Panchet Series.	Wianamatta Stage.	Hawkesbury Series.	..	..	..	Molteno Beds	Cacheuta Beds.	Sao Bento Series.
	Maleri Stage .		Hawkesbury Sandstone		..	Jerusalem Series.	Burrum Series.	..	..	..
	Panchet Stage .		Narrabeen Stage		..	..	..	Upper Beaufort Series.	..	..
PERMIAN.	Raniganj Stage .	Damuda Series.	Upper Coal Measures .		..	..	..	Lower Beaufort Series.	Red Beds and Sandstones.	Passa Dois Series.
	Ironstone Shales		Dempsey Beds . .		Bacchus Marsh Series.	Mersey and Potter's Hill Series.	Bowen River Coals.	..	..	..
	Barakar Stage .		Tomago Beds . .		..	..	..	Ecca Series .	..	..
UPPER CARBONIFEROUS.	Karharbari .	Talchir Series.	Upper Marine Beds (Glacial).		..	..	Bowen River Marine Beds (Glacial).	..	Coals and Shales.	Tubarao Beds.
					Bacchus Marsh Conglomerate (Glacial)	Upper Marine Beds with Coals (Glacial).	..	..	..	..
	Talchir (Glacial).		Greta Coal Measures .		..	..	..	Dwyka Conglomerate (Glacial).	Basal Conglomerate (Glacial).	Orleans Conglomerate (Glacial).
			Lower Marine Beds (Glacial).		..	..	..	..	..	..

Note.—This table is adapted, with various alterations and changes, from that given by Dr. D. White in the *Final Report on the Work of the Brazilian Coal Commission*, p. 381.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

RECORDS
OF
THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1917. [August.

THE MINERAL PRODUCTION OF INDIA DURING 1916. BY H. H. HAYDEN, C.I.E., F.R.S., *Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII), although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. The methods of collecting the returns are becoming more precise every year and the machinery

employed for the purpose more efficient. Hence the number of minerals included in Class I—for which approximately trustworthy annual returns are available—is gradually increasing, and it is hoped that before long the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will be reduced to a very small number. In the case of minerals still exploited chiefly under primitive native methods and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible, but the total error from year to year is not improbably approximately constant and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small native alluvial industry contributes such an insignificant portion to the total outturn that any error from this source may be regarded as negligible.

From Table 1 it will be seen that there has been an increase of nearly £1½ million or nearly 15 per cent. in the value of the total production over that of the previous year. Owing to the abnormal conditions prevailing throughout the year, the value of the outturn is hardly a reliable basis on which to judge of the relative prosperity of an industry; the details given in subsequent tables, however, will show that apparent increase in production is in all cases real and not merely due to temporarily inflated values. Of the ten most important minerals there has been a decrease in production and value in the case of only one, *viz.*, gold, and in that instance the decrease amounts only to less than 3 per cent. Very marked rises, on the other hand, have taken place in the production of manganese, saltpetre, wolfram and mica. This is due in each case to increased demand owing to the war. There has also been a considerable rise in the output of lead, and a very marked rise in the output of silver, in consequence of the steady development of the Bawdwin mines. The output of chromite and of magnesite has also increased largely, owing, in each case, to special demands from the United Kingdom.

Mineral concessions granted.

The number of licenses and leases granted during the year amounted to 532 as against 307 during the preceding year. 50 of these were mining leases and 482 prospecting licenses. The large increase in prospecting licenses was due chiefly to activity in Tavoy, where 227 prospecting licenses were granted.

TABLE 1.—*Total Value of Minerals for which returns of Production are available for the years 1915 and 1916.*

Mineral.	1915.	1916.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Coal	3,781,064	3,878,564	97,500	..	+2·6
Gold	2,369,846	2,303,023	..	66,823	—2·8
Manganese-ore	929,546	1,487,026	557,480	..	+60
Petroleum	1,065,182	1,119,405	54,223	..	+ 5
Salt	660,254	728,358	68,104	..	+ 10·3
Saltpetre	373,891	607,488	233,597	..	+62·5
Tungsten-ore	296,772	466,604	169,832	..	+57·2
Lead and Lead-ore	316,182	428,383	112,201	..	+35·5
Mica (*a*)	183,947	311,680	127,733	..	+69·4
Building Materials and road metal.	204,652	209,334	4,682	..	+2·3
Silver	31,150	88,687	57,537	..	+184·7
Tin-ore and Tin	54,980	71,416	16,436	..	+29·9
Jade Stone	52,070	48,926	..	3,144	—6
Iron-ore	31,886	37,981	6,095	..	+19·1
Monazite	33,238	37,714	4,476	..	+13·5
Ruby, Sapphire and Spinel.	36,298	37,513	1,215	..	+3·3
Chromite	3,531	16,401	12,870	..	+364·5
Magnesite	3,973	14,065	10,092	..	+254
Alum	4,393	6,205	1,812	..	+41·2
Zinc-ore	174	5,826	5,652	..	..
Clay	3,834	4,645	811	..	+21·2
Copper-ore	14,381	3,259	..	11,122	—77·3
Corundum	277	2,783	2,506	..	+904·7
Steatite	2,578	2,628	50	..	+1·9
Graphite	158	1,501	1,343	..	+850
Ochre	459	941	482	..	+105
Agate	1,019	783	..	236	—23·2
Gypsum	979	745	..	234	—23·9
Antimony-ore	236	503	267	..	+113·1
Bauxite	29	463	434	..	..
Diamond	603	361	..	242	—40·1
Molybdenite	..	202	202	..	..
Amber	199	157	..	42	—16
Platinum	100	46	..	54	—54
Total	**10,457,881**	**11,923,616**	1,547,632	81,897	+14·2
			$\underbrace{\qquad\qquad}_{\textbf{+1,465,735}}$		

(*a*) Export values.

II.—MINERALS OF GROUP I.

Chromite.	Graphite.	Magnesite.	Petroleum.	Saltpetre.
Coal.	Iron.	Manganese.	Platinum..	Silver.
Diamonds.	Jadeite.	Mica.	Ruby, Sapphire and Spinel.	Tin.
Gold.	Lead.	Monazite.	Salt.	Tungsten.
				Zinc.

Chromite.

There was a very marked increase in the output of chromite during the year 1916, the figures being the highest yet recorded and being only approached by those for 1907, when the output reached a total of over 18,000 tons, after which it fell rapidly to under 2,000 tons in 1910. The present recovery is due to changed conditions resulting from the war and to the consequent difficulties which have interfered with the industry in New Caledonia and Rhodesia. The Baluchistan chromite being of high grade, is in considerable demand, and a railway is now being constructed in order to make the mines more accessible. It is hoped that this will lead to a largely increased output. The output for 1916 was more than three times that of the preceding year, and amounted to 7,620 tons. There was also a very large increase in the output from Mysore which rose from a little over 1,000 tons in 1915 to nearly 10,000 tons in the year under review. In Singhbhum also there was a very considerable rise, and the present demand has led to increased activity in the latter district, where prospecting operations are now being vigorously carried out.

TABLE 2.—*Quantity and value of Chromite produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Baluchistan	2,161	2,161	7,620	7,620
Bihar and Orissa . . .	565	282	2,737	2,495
Mysore	1,041	1,088	9,802	6,286
Total .	**3,767**	***3,531***	**20,159**	***16,401***

Coal.

There was a small increase in quantity, and a relatively larger increase in the value, of coal produced during 1916 over the production for the preceding year, and although the conditions of the industry have become largely artificial in consequence of the war, the effect has not been to produce a decrease in production. The increase, however, would no doubt have been larger had it not been for the great scarcity of labour consequent on agricultural prosperity. The classes from which the colliery labour is recruited being largely agricultural, a favourable monsoon results in a shortage, since the miner leaves the collieries to cultivate his fields and only returns when his work is completed and his savings exhausted. The average pit's mouth value in Bengal rose from Rs. 3-6-2 in 1915 to Rs. 3-8-9, and in Bihar and Orissa from Rs. 2-15-6 to Rs. 2-15-10.

TABLE 3.—*Average price (per ton) of Coal extracted from the Mines in each province during the year 1916.*

Province.	Average price per ton. Rs. A. P.
Assam	6 15 10
Baluchistan	10 8 10
Bengal	3 8 9
Bihar and Orissa	2 15 10
Central India	3 0 0
Central Provinces	4 1 1
Hyderabad	6 0 0
North-West Frontier Province	5 0 0
Punjab	6 14 5
Rajputana	3 12 4

TABLE 4.—*Origin of Indian Coal raised during 1915 and 1916.*

—	Average of last five years.	1915.	1916.
Gondwana Coalfields	15,030.869	16,673,237	16,863,466
Tertiary Coalfields	408,747	430,695	390,843
Total .	..	**17,103,932**	**17,254,309**

There was a very large decrease in imports, which fell from over 200,000 tons in 1915 to less than 38,000 tons in 1916. Exports, on the other hand, rose appreciably, from a little over 753,000 in 1915 to nearly 882,000 tons in the year under review. There was a marked increase in the exports to the Straits Settlements and Sumatra. The above figures do not include exports by sea to Indian ports, which again fell very considerably ; those from Calcutta amounted only to 540,000 tons as against a little over 1,000,000 tons in 1915.

TABLE 5.—*Exports of Indian Coal.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Ceylon	554,885	343,202	548,105	339,054
Straits Settlements (including Labuan).	99,363	55,475	141,714	83,983
Sumatra	64,263	38,688	104,067	61,671
Other Countries	33,290	21,505	84,944	47,829
Total .	**751,801**	*458,870*	**878,830**	*532,537*
Coke	1,241	1,327	2,911	2,656
Total of coal and coke .	**753,042**	*460,197*	**881,741**	*535,193*

TABLE 6.—*Imports of Coal, Coke and Patent Fuel during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Australia (including New Zealand).	28,106	35,958	12,301	17,118
Japan	18,069	20,533	..	..
Natal	15,292	16,437	10,799	32,930
Portuguese East Africa	52,312	61,519	3,587	5,323
Transvaal	26,448	29,224	..	..
United Kingdom	30,149	45,948	1,418	3,378
Other Countries	3,075	3,303	1,852	2,596
Total	**173,451**	*212,922*	**29,957**	*61,345*
Coke	10,241	29,221	4,074	17,340
Patent Fuel	6,962	11,007	2	57
Government Stores	12,379	30,635	3,593	10,589
Total	**203,033**	*283,785*	**37,626**	*89,332*

There was again a reduction, amounting to nearly 200,000 tons, in the output of the Jharia coalfield, which produced 51·87 per cent. of the total Indian output in 1916 as against 53·44 per cent. in the preceding year. There was, on the other hand, a slight increase in the Raniganj coalfield, which produced 32·09 per cent. of the Indian total as against 32·07 in 1915. These two fields produced together about 84 per cent. of the Indian total, the next largest contributions being those of Giridih with 5·02 per cent. and Singareni with 3·56 per cent. There was a large increase in the output of Bokaro-Ramgarh from 10,232 tons in 1915 to over 197,000 tons in the year under review. The variations in the other coalfields were comparatively insignificant.

TABLE 7.—*Provincial Production of Coal during the years 1915 and 1916.*

Province.	1915.	1916.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Assam	311,296	287,315	..	23,981
Baluchistan	43,607	42,163	..	1,444
Bengal	4,975,460	4,992,376	16,916	..
Bihar and Orissa	10,718,155	10,767,683	49,528	..
Burma	25	..	..	25
Central India	139,680	200,285	60,605	..
Central Provinces	253,118	287,832	34,714	..
Hyderabad	586,824	615,290	28,466	..
North-West Frontier Province	60	75	15	..
Punjab	57,911	47,449	..	10,462
Rajputana (Bikaner)	17,796	13,841	..	3,955
Total	**17,103,932**	**17,254,309**	*190,244*	*39,867*

TABLE 8.—*Output of the Gondwana Coalfields for the years 1915 and 1916.*

Coalfields.	1915.		1916.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Bengal, Bihar and Orissa—				
Daltonganj	85,785	·50	76,298	·44
Giridih	872,647	5·10	866,055	5·02
Jaintia	40,730	·24	75,089	·44
Jharia	9,140,800	53·44	8,950,318	51·87
Bokaro-Ramgarh	10,232	·06	197,255	1·14
Raniganj	5,484,596	32·07	5,535,307	32·09
Sambalpur (Hingir-Rampur).	58,825	·34	59,737	·35
Central India—				
Umaria	139,680	·82	200,285	1·16
Central Provinces—				
Ballarpur	94,880	·56	84,889	·49
Pench Valley	103,152	·60	154,548	·9
Mohpani	55,086	·32	48,395	·28
Hyderabad—				
Singareni	586,824	3·43	615,290	3·56
Total	**16,673,237**	**97·48**	**16,863,466**	**97·74**

TABLE 9.—*Output of Tertiary Coalfields for the years 1915 and 1916.*

Coalfields.	1915.		1916.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Assam—				
Makum . . .	308,071		283,830	
Naga Hills . . .	2,872	1·82	3,135	1·66
Khasi and Jaintia Hills .	353		350	
Baluchistan—				
Khost	35,782	·21	32,995	·19
Sor Range . . .	7,825	·05	9,168	·05
Burma—				
Bhamo	25	..	..	..
North-West Frontier Province.	60		75	
Punjab—			44,944 817	
Jhelum	51,613	·34	1,688	·28
Mianwali . . .	2,029			
Shahpur . . .	4,269			
Rajputana—				
Bikaner . . .	17,796	·10	13,841	·08
Total .	**430,695**	**2·52**	**390,843**	**2·26**

There was a decrease of 3,500 in the number of persons employed daily in the coalfields, and the increase in the output in spite of this indicates an increase in efficiency, the output per person employed during 1916 being 110·21 tons as against 106·84 in the preceding year. The total number of fatal accidents was 211, giving a death-rate of 1·34 per 1,000 persons employed.

TABLE 10.—*Average number of persons employed daily in the Indian Coalfields during 1915 and 1916.*

Province.	Number of persons employed daily.		Output per person employed.	Number of deaths by accidents.	Death-rate per 1,000 persons employed.
	1915.	1916.	1916.	1916.	1916.
Assam . . .	2,909	2,814	102·1	8	2·84
Baluchistan . .	963	1,111	37·95	3	2·70
Bengal . . .	42,093	43,040	115·99	77	1·78
Bihar and Orissa .	95,292	92,053	116·97	109	1·18
Burma . . .	16	..	..	..	..
Central India . .	2,884	1,480	135·32	..	..
Central Provinces .	3,184	3,558	80·89	2	·56
Hyderabad . .	11,302	11,299	54·45	11	·97
North-West Frontier Province.	9	7	10·71	..	..
Punjab . . .	1,273	1,049	45·23	1	·95
Rajputana (Bikaner) .	161	143	96·79	..	..
Total .	**160,086**	**156,554**	..	211	..
AVERAGE .			110·21		1·34

Diamonds.

There was a further decrease in the output of diamonds, which fell to 20·42 carats, valued at £361. The whole production was from Central India.

Gold.

There was a decrease, amounting to over 18,000 ounces, in the total output of gold during the year under review. Most of this was due to decreased output from the Kolar gold-field.

TABLE 11.—*Quantity and value of Gold produced in India during 1915 and 1916.*

—	1915.		1916.		
	Quantity.	Value.	Quantity.	Value.	Labour.
	ozs.	£	ozs.	£	
Bihar and Orissa—					
Singhbhum . .	450	1,800	864	3,977	117
Burma—					
Myitkyina . .	3,106·83	11,913	1,901·05	7,289	
Katha . .	16·99	91	21·21	85	
Upper Chindwin .	50·25	295	46·96	276	242
Shwebo . .	7·31	36	7·41	36	
Salween . .	1·20	5	6]	24	
Hyderabad . . .	17,869·7	68,338	18,657·2	71,577	1,149
Madras . . .	23,870	101,324	22,371	94,789	1,937
Mysore . . .	571,199	2,185,409	554,301	2,124,129	25,258
Punjab . . .	149·59	604	186·23	810	369
United Provinces . .	7·37	31	7·63	31	29
Total .	**616,728·24**	*2,369,816*	**598,369·69**	*2,303,023*	**29,101**

Graphite.

The graphite industry, which was revised last year after having died out, has shown further progress, the output from Merwara in Rajputana having risen from 54 tons, valued at £147, in 1915 to 1,066 tons, valued at £1,333, in the year under review. There was also a considerable rise in the Kalahandi (Bihar and Orissa) output from 16 tons, valued at £11, in 1915, to 252 tons valued at £168 in 1916. Unfortunately, in both cases, the quality is low.

Iron.

There was a slight increase in the output of iron ore, which rose by about 20,000 tons to 411,758 tons in the year under review. Of this nearly 241,000 tons were won in Mayurbhanj State and over 150,000 tons in Singhbhum. The former material was employed by the Tata Iron & Steel Company, and the latter by the Bengal Iron & Steel Company. These companies produced 152,460 tons and 92,250 tons of pig iron, respectively, the Tata Iron & Steel Company producing also 92,902 tons of steel, including steel rails, and the Bengal Iron & Steel Company 30,605 tons of cast-iron castings. The iron ore produced in Burma was employed almost exclusively as flux in the smelting operations at the lead-zinc mines of Bawdwin. The only part of India in which the old indigenous methods of smelting are still carried on to any appreciable extent is the Central Provinces, which produced nearly 4,500 tons of ore and supported nearly 300 native furnaces.

TABLE 12.—*Quantity and Value of Iron ore produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bengal—				
Burdwan	2,243	370	..	..
Bihar and Orissa—				
Singhbhum	127,040	10,253	150,258	10,919
Orissa	240,321·8	16,032	240,918	21,271
Other Districts . .	386	103	..	..
Burma	15,526	4,140	16,081	4,288
Central Provinces . .	4,747	986	4,464·3	1,493
Rajputana	..	..	33·5	9
United Provinces . . .	6·7	2	3	1
Total .	**390,270·5**	*31,886*	**411,757·8**	*37,981*

Jadeite.

The quantity of jadeite produced in Burma rose from 3,692·75 cwt. in 1915 to 3,783·37 cwt. in the year under review. The estimated value of the raw product, however, decreased very considerably from £12,678 to £9,315. Exports of jadeite by sea fell slightly both in quantity and value from 5,001 cwt., valued at £52,070, in 1915 to 4,486 cwt. valued at £48,926. It has been pointed out more than once that the returns for jadeite are anomalous. The fact that the export values are very much higher than the production values is no doubt due to the increased value of the mineral after it has been cut; on the other hand, in spite of the fact that there seems to be a considerable loss in cutting, the quantities exported are invariably higher than the amounts produced. As, however, the jadeite mines lie in more or less unadministered territory, the figures relating to the industry must inevitably be only approximate; but the export figures are a fairly reliable indication of the state of the industry, which has, unfortunately, fallen off during recent years.

Lead.

The only lead mine of any importance being worked in the Indian Empire is that of Bawdwin, where a very large body of high-grade lead-zinc-silver ore has now been blocked out. For many years the smelting operations of the Company were directed to recovering lead and silver from the slags left by the old Chinese miners. Those slags, however, are now practically exhausted, and the mine has reached a stage of development at which a steady output of ore is assured. Nearly 9,000 tons of ore were produced during 1916 as against 4,000 tons in the preceding year. On the other hand, the production of slag fell from 32,534 tons in 1915 to 4,771 tons in the year under review. The total output of lead was 13,790 tons, valued at £428,065, and that of silver 759,012 ounces, valued at £88,552. Zinc has not yet been smelted at Bawdwin; before the war, the concentrates were exported to Belgium and Germany; exports practically ceased in 1914, but Japan took a certain quantity in 1916, the total exports during that year amounting to 3,224·6 tons, valued at £16,266.

TABLE 13.—*Production of Lead and Silver ore during 1915 and 1916.*

—	1915.			1916.		
	Quantity.	Value.		Quantity.	Value.	
	Lead-ore and slag.	Lead-ore and lead.	Silver.	Lead-ore and slag.	Lead-ore and lead.	Silver.
	Tons.	£	£	Tons.	£	£
Burma—						
Northern Shan States.	4,094 (ore)	36,301(*a*)	8,540	8,839 (ore)	273,850(*e*)	70,732
	32,534 (slag)	273,067(*b*)	20,258	4,771 (slag)	147,976(*f*)	15,989
	5,620 (gossan flux)	6,709(*c*)	2,301	202 (gossan flux)	6,239(*g*)	1,831
Southern Shan States.	28	75	..	143·58	275	..
Central Provinces—						
Drug . .	7	30	..	7	43	..
Kashmir . .	..	..	..	7·2(*h*)	..	..
Mysore—						
Chitaldrug .	..	..	..	1·78	(*i*)	..
Total .	**42,283**	*316,182*	*31,099(d)*	**13,971·56**	*428,383*	*88,552(j)*

(*a*) Value of 1,553 tons of lead extracted.
(*b*) Value of 11,682 tons of lead extracted.
(*c*) Value of 287 tons of lead extracted.
(*d*) Value of 284,875 ozs. of silver extracted.
(*e*) Value of 8,822 tons of lead extracted.
(*f*) Value of 4,767 tons of lead extracted.
(*g*) Value of 201 tons of lead extracted.
(*h*) Dug-out by a licensee under a prospecting license. Value not returned.
(*i*) Value not returned.
(*j*) Value of 759,012 ozs. of silver extracted.

Magnesite.

There was a very large increase in the output of magnesite, which rose from 7,450 tons, valued at £3,973, in 1915 to 17,640 tons, valued at £14,065, in the year under review. This marked increase was directly due to conditions resulting from the war, the supply required by United Kingdom not being available to the usual extent from Styria and other sources.

TABLE 14.—*Quantity and Value of Magnesite produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Madras	..	..	..	..
Salem	7,450	3,973	17,540	14,032
Mysore	..	..	100	33
Total .	7,450	3,973	17,640	14,065

Manganese.

There was a considerable increase in the output of manganese ore, which, however, is still considerably smaller than in pre-war years. Exports are entirely dependent on the requirements of the Allies, and the conditions at present ruling are therefore essentially artificial—a fact, which will be readily appreciated when it is pointed out that the average price per unit for 50 per cent. ore during 1916 was 2*s*. 6*d*. The exports during 1916 amounted to 580,328 tons.

TABLE 15.—*Export of Manganese ore during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
To—				
United Kingdom . .	353,036	410,277	433,519	515,090
France	7,501	9,477	59,471	71,389
United States of America	35,000	39,050	56,512	126,953
Other Countries . .	23,196	29,273	30,823	54,285
Total .	**418,733**	*488,077*	**580,328**	*767,717*

TABLE 16.—*Quantity and Value of Manganese ore produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value *f. o. b.* at Indian ports.	Quantity.	Value *f. o. b.* at Indian ports.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum . . .	507	993	2	4
Gangpur . . .	..	..	2,832	6,018
Bombay—				
Belgaum . . .	..	..	1,765	3,751
Chota Udepur . .	..	..	7,951	16,896
Panch Mahals . .	26,915	52,709	46,160	98,090
Central India—				
Jhabua	366	558	..	..
Central Provinces—				
Balaghat . . .	180,609	374,189	264,032	627,076
Bhandara . . .	78,627	166,427	86,344	205,067
Chhindwara . . .	46,941	99,358	53,977	128,195
Nagpur . . .	93,027	196,907	153,899	365,510
Jubbulpore . . .	11	23	576	727
Madras—				
Vizagapatam . . .	288	418	2,755	2,893
Mysore	23,125	37,964	24,911	32,799
Total .	450,416	*929,546*	645,204	*1,487,026*

Mica.

Owing to necessary restrictions with regard to the export of mica, the output fell off considerably in the year 1915, but subsequent demand in the United Kingdom for the best grade of ruby mica led to a considerable increase in production during the year under review, the total output being nearly 2,000 tons valued at over £109,000. The amount exported in 1916 was 2,735 tons,

TABLE 17.—*Quantity and Value of Mica produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
Bihar and Orissa	22,195	49,980	26,819·8	76,940
Madras	3.894	20,728	15,675	28,945
Mysore	8·7	33	18	72
Rajputana	1,042	3,398	887	3,287
Total	*27,139·7*	*74,139*	*43,399·8*	*109,244*

Monazite.

The position of the Travancore monazite industry remained practically unchanged. The output rose from 1,107·7 tons, valued at £32,238, in 1915 to 1,292·48 tons, valued at £37,714, in the year under review.

Petroleum.

There was a further increase, amounting to 10,000,000 gallons in the output of petroleum in Burma and India, the total production in 1916 being 297,189,787 gallons. The details of the respective fields are shown in table 18. So far as Burma is concerned, however, the returns are shown according to districts rather than by oil-fields, although in most cases only one field is included in a district. In the case of Magwe district, however, owing to a re-arrangement of boundaries, two fields, Yenangyaung and Singu, have been included in that district since July 1st, 1916, the date on which the Singu oil-field was transferred from the Myingyan district to Magwe. Consequently, the returns for Magwe include the production of Yenangyaung for the whole year and that of Singu for the second half of the year. On the other hand, the return shown under Myingyan gives the production of the Singu field for only the first six months of 1916. The actual production of that field was about 86,000,000 gallons, of which 44,000,000 gallons were produced during the first half of the year and are shown separately under Myingyan, while the remaining 42,000,000 gallons are included

in the returns for Magwe. Almost the whole of the increase in the output of India and Burma for the year is to be attributed to the Singu oil-field, of which the output increased by about 9,000,000 gallons. There was an insignificant decrease in the output of Yenangyaung. In India the Digboi field increased its output by about 750,000 gallons, while the new Khaur field in the Attock district of the Punjab produced slightly less than in 1915. Operations in that field, however, were still only in the experimental stage at the end of the year under review.

TABLE 18.—*Quantity and Value of Petroleum produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Gallons.	£	Gallons.	£
Burma—				
Akyab	12,045	231	11,882	228
Kyaukpyu . . .	23,220	716	68,843	321
Magwe (Yenangyaung and Singu).	198,809,315	765,240	240,194,063	924,534
Myingyan (Singu) . .	77,005,880	256,686	44,105,013	147,030
Pakokku (Yenangyat) .	4,099,345	15,525	5,310,740	19,980
Minbu	2,316,207	9,651	2,043,542	8,515
Thayetmyo . . .	25,920	108	35,000	293
Assam—				
Digboi (Lakhimpur) .	4,550,150	15,009	5,236,890	17,274
Punjab—				
Attock	250,000	2,000	182,480	1,216
Mianwali . . .	1,494	16	1,334	14
Total .	287,093,576	*1,065,182*	297,189,787	*1,119,405*

There was a decrease in imports of kerosine, chiefly in those from Borneo, which fell by about 30 per cent. There was also a small decrease in imports from America. Exports of paraffin wax, on the other hand, rose appreciably from a little over 19,000 tons in 1915 to 21,000 tons in 1916.

TABLE 19.—*Imports of Kerosine Oil during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Gallons.	£	Gallons.	£
From—				
Borneo	17,861,500	451,258	11,208,504	302,220
Persia	783,669	23,490	..	..
Straits Settlements (including Labuan).	6,156,330	161,489	5,375,469	175,864
United States of America	43,371,165	1,326,929	41,205,884	1,468,543
Other Countries . .	426	47	65,001	3,319
Total .	**68,173,090**	*1,963,213*	**57,854,858**	*1,949,946*

TABLE 20.—*Export of Paraffin Wax from India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
To—				
United Kingdom . .	153,267	221,974	119,317	169,662
China	46,551	57,551	38,101	52,623
Japan	57,500	87,209	95,069	145,545
Other Countries . .	126,983	192,263	171,831	259,497
Total .	**384,301**	*558,997*	**424,318**	*627,327*

Platinum.

The output of platinum at Myitkyina fell from 17·7 ounces in 1915 to 9·25 ounces in the year under review. The estimated value

of this outturn was £46. Platinum is said to occur in association with gold in many of the valleys on the frontiers of Northern Burma, and it is hoped that this matter may be taken up for investigation at an early date.

Ruby, Sapphire and Spinel.

There was an appreciable decrease in the quantity, but a small increase in the value, of the outturn of the Ruby Mines during the year under review. The total amount won was 209,724 carats, valued at £37,513.

TABLE 21.—*Quantity and Value of Ruby, Sapphire and Spinel produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Carats.	£	Carats.	£
Burma—				
Mogok	167,904 (Rubies)	34,881	136,783 (Rubies)	35,848
	39,718 (Sapphires)	1,276	34,100 (Sapphires)	1,442
	43,827 (Spinel)	141	38,841 (Spinel)	223
Total .	251,449	*36,298*	209,724	*37,513*

Salt.

There was a considerable decrease in the amount of salt produced during 1916 as compared with the production of the preceding year. The production of Aden fell off by nearly 63 per cent., while that of Northern India, including Sambhar Lake, fell by about 27 per cent. The total output amounted nearly to 1,500,000 tons, valued at a little under £750,000. The output of rock-salt from the mines in the Salt Range rose slightly to nearly 185,000 tons. There was a further fall in imports from a little under 520,000 tons to a little over 446,000 tons.

TABLE 22.—*Quantity and Value of Salt produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Aden	352,232	47,838	129,406	45,614
Bengal	(a)	..	2	1
Bombay and Sind . .	524,257	129,180	484,742	128,420
Burma	28,521	108,870	38,774	184,812
Central India . . .	..	..	6·7	32
Gwalior State . . .	127	347	114	364
Kashmir	36·7	27	36·7	27
Madras	345,714	209,897	481,170	267,065
Northern India . . .	494,634	164,095	354,398	102,023
Total .	1,745,521·7	*660,254*	1,488,649·4	*728,358*

(a) Quantity of salt educed was 24½ maunds (nearly 1 ton), valued at Rs. 9-3-0.

TABLE 23.—*Quantity and Value of Rock-Salt produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Salt Range	154,772	26,332	160,358	27,283
Kohat	21,387	2,123	19,978	1,983
Mandi	3,633	4,327	4,568	5,440
Total .	179,792	*32,782*	184,904	*34,706*

TABLE 24.—*Quantity and Value of Salt imported into India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Aden and Dependencies .	102,286	108,995	96,465	169,586
Egypt	125,123	224,218	115,429	296,364
Germany	1,020(*a*)	926	..	..
Spain	102,286	152,736	80,893	200,734
Turkey, Asiatic . . .	..	2	..	..
United Kingdom . . .	131,018	138,478	109,972	233,289
Other Countries . . .	57,790	52,617	43,432	74,190
Total .	**519,523**	*677,972*	**446,191**	*974,163*

(*a*) From prize cargoes.

Saltpetre.

The revival in the saltpetre industry recorded in last year's review has been fully maintained, and the output rose from 18,000 tons in 1915 to 25,000 tons in the year under review, that is to say, the production has almost been doubled in the course of the last three years, and there is reason to believe that the industry is capable of still further expansion. The estimated value of the output for 1916 is £607,448.

TABLE 25.—*Quantity and Value of Saltpetre produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar	5,673	113,147	5,904	143,188
Central India . . .	..	..	25·1	481
Punjab	5,253	109,548	8,140	191,878
Rajputana	137	2,568	244	5,700
United Provinces . . .	7,035	148,628	10,743	266,241
Total .	**18,098**	*373,891*	**25,056·1**	*607,488*

TABLE 26.—*Distribution of Saltpetre exported during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
Ceylon	57,221	45,393	18	29
China	31,692	27,335	..	..
Mauritius and Dependencies	15,146	13,408	..	..
United Kingdom	296,106	315,372	428,099	559,154
United States of America	..	..	19,984	25,230
Other Countries	18,443	20,876	36,880	53,711
Total	**418,608**	*422,384*	**484,981**	*638,124*

Silver.

Part of the output of silver has already been shown under the heading *Lead*, silver being obtained as a by-product in the smelting of the lead-zinc ores of Bawdwin. The output from that source during 1916 was 759,012 ounces, being an increase of nearly 500,000 ounces over the output of the preceding year. There was also a considerable increase in the Anantapur output, which, however, only amounted to 1,362 ounces as against 512 ounces in the preceding year.

TABLE 27.—*Production of Silver during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Ozs.	£	Ozs.	£
Burma—				
Northern Shan States	284,875	31,099	759,012	88,551
Madras—				
Anantapur	512	51	1,362[1]	136
Total	**285,387**	*31,150*	**760,374**	*88,687*

[1] Won from Anantapur Gold Mines.

Tin.

While the output of block tin fell slightly, from 2,555 cwt. to 2,257 cwt., that of tin-ore rose by more than 50 per cent., from 8,629 cwt. in 1915 to 13,013 cwt. in the year under review. Most of this ore came from the Southern Shan States. Appreciable quantities, however, were also derived from Mergui and Tavoy. Recently tin-bearing alluvium, said to be both rich and extensive, has been found in the Thaton district of Lower Burma; only 45 tons were won during the year but it is probable that a very appreciable quantity will be recorded in next year's returns. There was a further fall in imports of block tin.

TABLE 28.—*Quantity and Value of Tin and Tin-ore for the years 1915 and 1916.*

	1915.				1916.			
	Block Tin.		Tin Ore.		Block Tin.		Tin Ore.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£	Cwt.	£	Cwt.	£
Bihar and Orissa—								
Hazaribagh	·7	6	..	..	..	..	..	..
Burma—								
Amherst	..	..	..	..	..	..	10	16
Mergui	2,553·5	20,534	1,762·25	8,678	2,257·19	19,802	1,897·1	510,531
Southern Shan States.	..	..	6,613·9	24,802	..	..	8,561·5	129,277
Tavoy	·6	4	253	956	..	..	1,644	8,192
Thaton	..	..	..	..	..	..	900	3,598
Total	2,554·8	*20,544*	8,629·15	*34,436*	2,257·19	*19,802*	13,012·66	*51,614*

TABLE 29.—*Imports of Tin unwrought (blocks, ingots, bars and slabs) into India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
From—				
United Kingdom . .	2,722	23,670	1,455	13,839
Straits Settlements (including Labuan).	27,014	224,524	23,450	211,999
Other Countries . .	466	3,883	1,025	9,430
Total .	**30,202**	*252,077*	**25,930**	*235,268*

Tungsten.

The results of the energetic measures adopted by the Government of Burma in order to increase the production of wolfram in that province are visible in the output for 1916, which rose to 3,761 tons, being an increase of over 1,100 tons over the preceding year and considerably more than double the output of any year previous to the war. Most of the output came from Tavoy, the production of which rose to 2,690 tons, an increase of more than 650 tons over the preceding year. Some old dumps at Agargaon in Nagpur district were cleaned up and exported, resulting in the production of 1·3 ton. Further attempts to find workable deposits in the same locality have not met with any success. Singhbhum, however, has now been added to the wolfram-producing localities; a small parcel of 8 tons, valued at only £640, was produced in that district.

TABLE 30.—*Quantity and Value of Tungsten-ore produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum . . .	..	..	8	640
Burma—				
Mergui	232·3	29,554	528·6	53,566
Southern Shan States .	330·7	24,802	428·1	29,277
Tavoy	2,032·9	235,827	2,689·8	366,428
Thaton	49·4	6,589	72·7	10,115
Central Provinces—				
Nagpur . . .	..	..	1·3	220
Rajputana—				
Marwar . . .	..	..	32·7	6,358
Total .	**2,645·3**	*296,772*	**3,761·2**	*466,604*

Zinc.

See under *Lead*.

III.—MINERALS OF GROUP II.

Agate. There was a marked decrease in the output of agate, from 508 tons in 1915 to 143 tons valued at £783 in the year under review.

Alum. The output of alum from Mianwali district in the Punjab rose from 7,026 cwt. in 1915 to 9,419 cwt. in 1916. The estimated value of the outturn was £6,205.

Amber. The output of amber fell by nearly 50 per cent., and was only 5½ cwt. valued at £157. It all comes from the Myitkyina district of Burma.

Antimony. There was a considerable demand during the year 1916 in the United Kingdom for ores of antimony. At present these are known to occur only in small quantities in the Indian Empire, chiefly in Mysore and in Burma. The former province produced 40 tons, and the latter 1,000 tons from the Amherst district, where the ore is said to occur in at least two localities. It is proposed to take this matter up in the immediate future with a view to the investigation of the deposits. The estimated value of the total outturn for 1916 was £503.

TABLE 31.—*Quantity and Value of Antimony Ore produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Burma— Amherst	13	231	1,000	500
Mysore— Chitaldrug	..	..	40	(*b*)
Punjab— Jhelum	(*a*)	5	(*c*)	3
Total	13	*236*	1,040	*503*

(*a*) Quantity produced was only 2·06 lbs.
(*b*) Value not returned.
(*c*) Quantity produced was only 4·11 lbs.

Aquamarine. 4·13 cwts. of aquamarine were won in the Skardu tahsil of Kashmir. The value of this is not at present known, as the market is uncertain; the quality of the stones, however, is good. A certain amount of the production has been disposed of at from 4½ to 7 annas per carat.

Bauxite. The output of bauxite, from the Jubbulpore district of the Central Provinces, amounted to 750 tons valued at £463.

Building-stones. The total estimated value of building-stones and road-metal produced during the year 1916 is £209,334. These figures, however, are incomplete.

Clay. The figures for clay are also incomplete; they show an output of 66,861 tons valued at £4,645.

Copper. The output of copper ore fell from 8,885 tons in 1915 to 2,671 tons in the year under review. The greater part of the production (2,173 tons) came from the Cape Copper Co.'s mines in Singhbhum district, and the remainder (498 tons) from Messrs. Jamal Brothers & Co.'s exploratory workings in Katha district, Burma.

Corundum. There was a very large increase in the output of corundum during the year 1916, the production having risen from 62 tons in the preceding year to 1,868 tons in the year under review. The estimated value of the output was £2,783.

TABLE 33.—*Quantity and Value of Corundum produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Cwts.	£	Cwts.	£
Assam—				
Khasi and Jaintia Hills .	..	..	36,540	2,555
Central India—				
Rewah State . .	290	81	743	207(*a*)
Madras—				
South Canara . .	37	12	38	13
Mysore	919	184	40	8
Total .	**1,246**	***277***	**37,361**	***2,783***

(*a*) Represents royalty realised by the State.

TABLE 32.—*Production of Building Materials and Road Metal in India during the year 1916.*

	GRANITE.		LATERITE.		LIME.		LIMESTONE AND KANKAR.		MARBLE.		SANDSTONE.		SLATE.		TRAP.		MISCELLANEOUS.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£
Assam .	..	..	..	..	..	..	87,425	5,609	..	..	..	..	..	..	..	..	..	..
Bihar and Orissa.	15,740	3,523	38,845	1,248	250	7	288,040	34,898	..	..	57,098	1,877	2,236	2,264	44,975	1,275	211,576	6,830
Bombay .	..	..	..	..	..	..	5,000	100	..	..	..	..	..	..	..	..	..	..
Burma .	219,153	18,388	222,514	17,199	..	..	130,709	8,131	..	..	57,480	5,541	..	..	1,895	72	269,946	16,746
Central India	..	..	..	..	16,201	8,626	12,792	2,511	..	..	..	..	..	..	..	..	48,238	290
Central Provinces.	..	..	..	..	..	..	15,555	3,488	143	237	..	..	..	..	..	..	1,365	20
Hyderabad .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Madras .	305,131	4,927	200,696	5,117	..	..	13,964	794	..	..	..	..	..	..	..	..	106,163	6,895
North-West Frontier Province.	..	..	..	..	..	..	7,037	317	..	..	..	..	..	..	..	..	..	..
Punjab .	..	..	..	..	..	..	23,492	1,296	..	..	137,579	8,118	7,208	7,177	..	..	5,714	89
Rajputana .	..	..	..	..	..	..	810	478	3,814	2,131	40,574	11,765	..	..	..	..	40,032	2,961
United Provinces.	..	..	..	..	114	117	38	5	..	..	3,927	1,233	49,353	322	..	..	122,099	16,709
TOTAL .	**540,024**	*26,838*	**462,055**	*23,564*	**16,565**	*8,750*	**644,862**	*57,630*	**3,957**	**2,368**	**296,658**	*28,534*	**58,797**	*9,763*	**46,870**	*1,347*	**805,133**	*50,540*

Garnet. The garnet industry of Rajputana completely disappeared during the year, but there was an output of 395 cwt. of garnet sand from Hyderabad (Deccan) and 80 cwt. from Mysore.

Gypsum. The production of gypsum fell from 22,563 tons, valued at £979, in 1915 to 16,028 tons, valued at £745, in the year under review. Almost the whole of this (15,413 tons) came from Rajputana.

Ilmenite. A small quantity of ilmenite (2 tons), valued at £12, was won in the Thaton district of Burma. It was won and exported accidentally, under the impression that it was wolfram.

Molybdenite. A small quantity of molybdenite, amounting to 8 cwt. and valued at £202, was won from the wolfram mines in Tavoy. Discoveries of molybdenite ore in Southern India were recorded and several localities visited. None of these, however, proved to be of any value.

Ochre. The output of ochre rose to 850·5 tons valued at £941. Of this 839 tons came from Central India, 8 tons from the Central Provinces and 3½ tons from Bihar and Orissa.

Steatite. There was a slight rise in the production of steatite.

TABLE 34.—*Quantity and Value of Steatite produced in India during 1915 and 1916.*

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum . . .	(*a*)	333	(*a*)	250
Mayurbhanj . . .	50	133	52	333
Central Provinces—				
Jubbulpore . . .	329	336	891·75	794

(*a*) Quantity not returned.

TABLE 34.—*Quantity and Value of Steatite produced in India during 1915 and 1916*—contd.

—	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Madras—				
Bellary	28	19	36	12
Kurnool . . .	..	..	10·45	116
Nellore	45·75	407	50 5	251
Salem	529·4	720	87	325
United Provinces—				
Hamirpur . . .	95	630	76	504
Jhansi	..	..	10	43
Total .	1,077·15	*2,578*	1,213 7	*2,628*

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 35.—*Statement of Mineral Concessions granted during 1916.*

ASSAM.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cachar .	(1) Mr. W. Gordon Stoker on behalf of Badarpur Oil Co.	Oil . . .	P. L. (renewal).	3,180·8	9th May 1916	1 year.
Khasi and Jaintia Hills.	(2) Mr. R. D. Coggan .	Gold and certain other allied minerals.	P. L. (renewal)	12,704	14th March, 1916.	Do.
Do. .	(3) Do. .	Tin and wolfram .	P. L. (renewal)	12,704	Do. .	Do.
Do. .	(4) Do. .	Gold, tin and certain other allied minerals.	P. L. (renewal).	8,160	Do. .	Do.
Lakhimpur	(5) Assam Railways and Trading Co.	Coal, oil, iron, slate and shales.	P. L.	25,600	9th March, 1916.	Do.

BALUCHISTAN.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kalat. .	(6) The Burma Oil Co., Ltd.	Oil . .	P. L. .	24,960	18th December, 1915.	1 year.
Do. .	(7) Messrs. Sorabji & Co. of Quetta.	Coal . .	M. L. .	80	1st July, 1916.	30 years.
Do. .	(8) Khan Bahadur B. D. Patel, C.I.E. of Quetta.	Do. . .	M. L. .	80	Do. .	Do.
Quetta-Pishin.	(9) General Manager, Baluchistan Chrome Co., Ltd.	Chrome . .	M. L. .	160	Do. .	Do.
Do. .	(10) Do. .	Do. . .	P. L. .	80	1st August, 1916.	1 year.
Sibi . .	(11) W. C. Clements, Esq., through his agent Babu Ganda Singh.	Coal . .	M. L. .	80	1st July, 1916.	30 years.
Zhob . .	(12) Khan Bahadur B. D. Patel, C.I.E., Quetta.	Chromite . .	M. L. .	80	1st July, 1917.	Do.
Do. .	(13) Do. .	Do. . .	M. L. .	80	Do. .	Do.
Do. . .	(14) Do. .	Do. . .	M. L. .	80	Do. .	Do.
Do. . .	(15) Do. .	Do. . .	M. L. .	80	Do. .	Do.
Do. . .	(16) General Manager, Baluchistan Chrome Co., Ltd.	Do. . .	M. L. .	2,823	1st July, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BIHAR AND ORISSA.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh	(17) Jagannath Rosen Lal.	Mica . . .	P. L. .	310	13th July, 1916.	1 year.
Singhbhum	(18) Babu N. N. Goswami of Calcutta.	Manganese . .	P. L. .	8·36	15th February, 1916.	Do.
Do. .	(19) Mr. A. C. Moitra of Calcutta.	Gold, manganese and bauxite.	P. L. . (renewal).	320	4th June, 1916.	Do.
Do. .	(20) Rai Srinath Pal Bahadur of Calcutta.	Manganese . .	P. L. . (renewal).	1,920	6th November, 1915.	Do.
Do. .	(21) Mr. Philip E. Billinghurst of Calcutta.	Chromite and associated minerals.	P. L. .	67·20	19th May, 1916.	Do.
Do. .	(22) Do. .	Do. .	P. L. .	184·32	Do. .	Do.
Do. .	(23) Do. .	Do. .	P. L. .	200	Do. .	Do.
Do. .	(24) Mr. S. Luxman Rao Naidu of Nagpur. .	Chromite . .	P. L. .	572·32	1st May, 1916.	Do.
Do. .	(25) Messrs. Rolfe Morris & Co., Calcutta.	Iron, chromite, manganese, wolfram, Galena and allied ores.	P. L. .	about 3,200	License not yet executed.	Do.
Do. .	(26) Babu N. N. Goswami of Calcutta.	Chromite . .	M. L. .	41·42	Lease not yet executed.	20 years.
Do. .	(27) Do. .	Manganese . .	P. L. .	33·70	10th June, 1916.	1 year.
Do. .	(28) Do. .	Yellow ochre .	M. L. .	6·74	Lease not yet executed.	5 years.
Do. .	(29) Do. .	Do. .	M. L. .	2·86	Do. .	Do.
Do. .	(30) Do. .	Red ochre . .	M. L. .	1·6	Do. .	1 year.
Do.	(31) Rai Srinath Pal Bahadur of Calcutta.	Manganese . .	M. L. .	240	Do. .	30 years.
Do. .	(32) Babu Modhu Lal Doogar of Calcutta.	Chromite . .	P. L. .	704	License not yet executed.	1 year.
Do. .	(33) Babu A. C. Moitra of Calcutta.	Do. . .	P. L. .	224	1st August, 1916.	Do.
Do. .	(34) Babu N. N. Goswami of Calcutta.	Do. . .	P. L. .	143·66	20th September, 1916.	Do.
Do. .	(35) Do. .	Manganese . .	P. L. .	1,280	22nd September, 1916.	Do.
Do. .	(36) Messrs. Rolfe Morris & Co., Calcutta.	Iron, chromite, manganese, tungsten, gold, galena and allied minerals.	P. L. .	2,240	License not yet executed.	Do.
Do. .	(37) Do. .	Do. .	P. L. .	800	Do. .	Do.
Do. .	(38) Do. .	Do. .	P. L. .	320	Do. .	Do.
Do. .	(39) Do. .	Do. .	P. L. .	960	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BIHAR AND ORISSA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Singhbhum.	(40) The Singhbhum Chromite Co., Ltd., Calcutta.	Chromite . .	P. L. .	3,136	5th June, 1916.	Under rule 30 (i) of the current Mining Rules, the period of the license has been extended from 7th July, 1916, until a mining lease for the area is granted.
Do. .	(41) The Singhbhum Chromite Co., Ltd., Calcutta, (Messrs. Rae & Co., Managing Agents).	Do. . .	M. L.	41·42	Lease not yet executed.	For the term of the war.
Do.	(42) Mr. S. Luxman Rao Naidu of Nagpur.	Do. . .	P. L. .	596·30	16th July, 1916.	Period extended under rule 30 (i) proviso pending the grant of a mining lease.
Do. .	(43) Do. .	Do. . .	P. L. .	216	Do. .	Do.
Do. .	(44) The Bengal Iron and Steel Co., Ltd., Kulti.	Manganese and Iron-ore.	P. L. .	990	21st December, 1916.	1 year.
Do. .	(45) The Tata Iron and Steel Co. Ltd., Sakchi.	Iron-ore . .	P. L. .	1,939·2	License not yet executed.	Do.
Do. .	(46) Do. .	Do. . .	P. L. .	8,176	Do. .	Do.

BOMBAY.

Panch Mahals	(47) The Bamankua Manganese Co., Ltd.	Manganese . .	P. L. (renewal).	506·8	17th April, 1916.	1 Year.
Do. .	(48) H. J. Winch, Esq., Mine Manager, Shivrajpur Syndicate, Ltd.	Do. . .	P. L. .	45·5	5th October, 1916.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Akyab .	(49) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. .	5,440	15th December, 1916.	1 year.
Amherst .	(50) Dr. K. S. Kanga .	All minerals (except oil).	P. L. .	640	14th March, 1916.	Do.
Do. .	(51) The Hon'ble Mr. Lim Chin Tsong.	Do. .	P. L. .	1,280	18th February, 1916.	Do.
Do. .	(52) Do. .	Do. .	P. L.	320	9th December, 1915.	Do.
Do. .	(53) Mr. H. E. Singleton	Do. .	P. L. .	309	28th March, 1916.	Do.
Do. .	(54) Mr. C. E. Law .	Gold, silver, copper, wolfram and antimony.	P. L. . (renewal).	960	15th November, 1915.	Do.
Do. .	(55) Maung Pe . .	All minerals (except oil).	P. L. .	640	17th June, 1916.	Do.
Do. .	(56) Chew Whee Shain .	Tin, wolfram, lead, gold, copper, silver and antimony.	P. L. .	640	19th April, 1916.	Do.
Do. .	(57) Saw Bein Nga .	All minerals (except oil).	P. L. .	640	20th April, 1916.	Do.
Do. .	(58) Do. .	Do. .	P. L. .	640	29th May, 1916.	Do.
Do. .	(59) Maung Pu . .	Do. .	P. L. .	448	24th August, 1916.	Do.
Do. .	(60) Maung Tun Hla .	Do. .	P. L. .	640	11th September, 1916.	Do.
Do. .	(61) Mrs. M. M. Hla Aung	Do. .	P. L .	640	18th July, 1916.	Do.
Do. .	(62 Chee Whee Shain .	Do. .	P. L. .	640	27th September, 1916.	Do.
Do. .	(63) Do. .	Do. .	P. L. .	640	Do. .	Do.
Do. .	(64) Messrs. T. D'Castro & Son.	Do. .	P. L. .	1,280	2nd September, 1916.	Do.
Do. .	(65) Maung Hpaung .	Do. .	P. L. .	640	9th September, 1916.	Do.
Do. .	(66) Mrs. M. M. Hla Oung.	Do. .	P. L .	640	5th September, 1916.	Do.
Do. .	(67) Saw Bin Nga .	Do. .	P. L .	1,024	27th September, 1916.	Do.
Do. .	(68) Messrs. The Talaing Exploration Syndicate.	Do. .	P. L. .	2,880	17th November, 1916.	Do
Do. .	(69) Do. .	Do. .	P. L.	640	Do. .	Do
Do. .	(70) Chew Whee Shain .	Do. .	P. L. .	640	27th September, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Amherst	(71) Chew Whee Shain	All minerals (except oil).	P. L.	640	27th September, 1916.	1 year.
Do.	(72) Dr. K. S. Kanga	Graphite	P. L.	50	15th November, 1916.	Do.
Do.	(73) Maung Han	All minerals (except oil).	P. L.	640	6th December, 1916.	Do.
Katha	(74) Messrs. Jamal Bros. & Co., Ltd.	Tin, wolfram, silver, copper, lead, zinc and gold.	P L.	24,320	3rd November, 1915.	Do.
Do.	(75) Do.	Tin, wolfram, silver and copper.	P. L. (renewal).	4,800	22nd June, 1916.	Do.
Do.	(76) A. M. Hoosain Hamadanee.	Zinc, lead and silver.	P. L. (renewal).	960	26th June, 1916.	Do.
Kyaukpyu	(77) Messrs. The Burma Oil Co., Ltd.	Mineral oil.	P. L.	2,105·6	11th December, 1916.	Do.
Lower Chindwin.	(78) Messrs. Jamal Bros. & Co., Ltd.	All minerals (except oil).	P. L. (renewal.)	140	23rd March, 1916.	Do.
Do.	(79) Do.	Do.	P. L (renewal)	1,120	Do.	Do.
Do.	(80) A. K. A. S. Jamal	Do.	P. L. (renewal).	1,680	Do.	Do.
Do.	(81) Messrs. Jamal Bros. & Co., Ltd.	Copper	P. L.	1,440	1st August, 1916.	Do.
Do.	(82) Messrs. The Burma Oil Co., Ltd.	Mineral oil	P. L.	960	1st May, 1916	Do.
Magwe	(83) Do.	Do.	P. L.	3,840	3rd March, 1916.	Do.
Mandalay	(84) R. N. Iyer	All minerals (except oil).	P. L.	2,560	15th December, 1916.	Do.
Mergui	(85) Yew Shwe Ni.	Do.	P. L.	1,449	28th January, 1916.	Do.
Do.	(86) Maung E. Gyi	Do.	P. L.	1,775·52	13th March, 1916.	Do.
Do.	(87) Meera Saib	Do.	P. L.	327·68	19th January, 1916.	Do.
Do.	(88) Miss L. Jewett	Do.	P. L.	2,990·08	Do.	Do.
Do.	(89) C. Soo Don	Do.	P. L.	1,176·64	28th February, 1916.	Do.
Do.	(90) Nyaung Tat	Do.	P. L.	353	13th March, 1916.	Do.
Do.	(91) Mrs. M. La Bouchadiere.	Do.	P. L.	640	24th March, 1916.	Do.
Do.	(92) M. Haniff	Do.	P. L. (renewal).	2,580·48	6th January, 1916.	Do.
Do.	(93) U. Po Tsee	Do.	P. L. (renewal).	381·44	22nd March, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(94) U Shwe I . .	All minerals (except oil).	P. L. (renewal).	473 60	9th February, 1916.	One year or until mining lease applied for is issued or refused.
Do. .	(95) Maung Shwe Don .	Do. .	P. L (renewal).	793 60	Do. .	8 months and 23 days.
Do. .	(96) Maung Shwe Thi .	Do. .	P. L. (renewal).	852 48	14th August, 1916.	6 months.
Do. .	(97) Saw Lein Lee. .	Do. .	P. L. (renewal).	664 48	1st September, 1916	1 year.
Do. .	(98) U Po Tsee . .	Do. .	P. L. .	480	25th November, 1916	Do.
Do. .	(99) Nyaung Tat . .	Tin and wolfram .	P. L. .	1,330	19th December, 1916	Do.
Do.	(100) Akbar Shah .	All minerals (except oil).	P. L. .	3,200	Do .	Do.
Do. .	(101) Gul Mahomed .	Do. .	P. L. .	125 77	6th December, 1916	Do.
Do. .	(102) Maung Po . .	Do. .	P. L. .	200	22nd December, 1916	Do.
Do. .	(103) Mr E. Ahmed .	Do. .	P L. .	2,560	21st December, 1916	Do.
Do. .	(104) U Shwe I . .	Do .	P L (renewal)	2,816	23rd March, 1916	Do.
Do. .	(105) Maung Shwe Don	Do. .	P L (renewal).	793 60	1st November, 1916.	3 months.
Do. .	(106) Messrs. Wightman & Co.	Do. .	P L. (renewal).	808 96	26th August, 1916.	1 year.
Minbu .	(107) Messrs. The British Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. .	174	6th March, 1916.	Do.
Do.	(108) Maung Han .	Do. .	P. L. .	640 acres western halves of blocks 14 S and 16 S in the Minbu oil field.	2nd June, 1916.	Do.
Do. .	(109) M. E. Bymeah & Co.	Do. .	P. L. .	320 acres western half of block 1 S in the Minbu oil field.	8th July, 1916.	Do.

P. L.=*Prospecting License* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Minbu .	(110) Messrs. The British Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. . (renewal).	410·32 acres (southern half of block 16 N. and northern portion of block 17 N. in the Minbu oil field).	12th August, 1916.	1 year.
Do. .	(111) Messrs. The Yomah Oil Co.	Do. .	M. L. .	501 acres (Block 20 P. of the Minbu oil field).	23rd February, 1916.	30 years.
Do. .	(112) Messrs The British Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	640	17th August, 1916.	1 year.
Do. .	(113) Do. .	Do. .	P L (renewal).	614·4	Do. .	Do.
Myingyan .	(114) Messrs. The Burma Oil Co , Ltd.	Do. .	P. L. .	2,813 3	4th March, 1916.	Do.
Myitkyina .	(115) Messrs. The Burma Gold Dredging Co. 1911, Ltd.	Gold and Irido-Platinum.	P. L. .	3,200	22nd February, 1916.	Do
Do. .	(116) Mr. H. F. Leslie .	Gold . . .	P L. (renewal).	640	1st November, 1916.	Do.
Northern Shan States.	(117) Messrs. The Mohochaung Exploration Co.	Gold, silver, lead, iron and zinc.	P. L. (renewal).	3,200	9th April, 1916.	Do.
Pakôkku .	(118) Messrs. Balthazar & Son, Rangoon.	Mineral oil . .	P. L. .	1,280	28th January, 1916.	Do.
Do. .	(119) Messrs. The Rangoon Oil Co., Ltd.	Do. . .	P. L. .	320	16th August, 1916.	Do.
Do. .	(120) Messrs. The British Burma Petroleum Co., Ltd.	Do. . .	P. L. .	640	Do. .	Do.
Do. .	(121) Messrs. the Nath Singh Oil Co., Ltd.	Do. .	P. L. .	1,920	12th January, 1916.	Do.
Do.	(122) Do. .	Do. . .	P. L. .	12,399·4	26th April, 1916.	Do.
Do. .	(123) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	351·63 acres Block D 2 of the Yenangyat oil field.	24th July, 1916.	Do.
Prome	(124) Messrs. the Burma Oil Co., Ltd.	Do . .	P. L. (renewal).	3,200	8th June, 1916.	Do.
Do. .	(125) Do. .	Do. . .	P. L (renewal).	3,200	7th June, 1916.	Do.
Shwebo .	(126) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L .	7,040	22nd May, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Southern Shan States.	(127) Ko Law Pan .	Mica . . .	P. L. .	640	15th March, 1916.	1 year.
Do. .	(128) Messrs. A. V. Joseph & Co.	Wolfram . .	P. L. .	1,600	12th April, 1916.	Do.
Do. .	(129) Saw Lein Lee .	All minerals (except oil).	P. L. .	599	30th May, 1916.	Do.
Do. .	(130) Maung San Hein .	Do. .	P. L. .	800	5th June, 1916.	Do.
Do. .	(131) Mr. R. E. Smith .	Do. .	P. L. (renewal).	3,040	15th June, 1916.	Do.
Do. .	(132) Messrs. Osman Musti Khan & Co.	Do. .	P. L. .	3,840	1st July, 1916.	Do.
Do. .	(133) The Hon'ble Mr. Lim Chin Tsong.	Lead . . .	P. L. .	640	30th August, 1916.	Do.
Do. .	(134) Maung San Hein .	All minerals (except oil).	P. L. .	640	15th August, 1916.	Do.
Do. .	(135) Messrs. Jamal Bros. & Co., Ltd.	Do. .	P. L. (renewal).	5,446	26th June, 1916.	Do.
Do. .	(136) Mr. John Terndrup	Gold, galena, copper, tin and wolfram.	P. L. (renewal).	3,200	13th July, 1916.	Do.
Do. .	(137) Maung Pan Aung .	All Minerals (except oil).	P. L. (renewal).	640	4th August, 1916.	6 months
Do. .	(138) Ko Law Pan .	Do. .	P. L. (renewal).	360	21st August, 1916.	1 year.
Do. .	(139) Htamon Ye .	Wolfram . .	P. L. .	191·40	7th October, 1916.	Do.
Do. .	(140) Messrs. Jamal Bros. & Co.	All Minerals (except oil).	P. L. .	1,280	28th November, 1916.	Do.
Do. .	(141) Mr. H. E. Singleton	Antimony and associated metals except mineral oil.	P. L. .	640	23rd October, 1916.	Do.
Do. .	(142) Mahomed Nazeer .	Wolfram . .	P. L. .	1,702·5	4th November, 1916.	Do.
Do. .	(143) Do. .	Do. . .	P. L. .	1,280	27th October, 1916.	Do.
Tavoy .	(144) Mr. Crawshaw .	All minerals (except oil).	P. L. .	1,280	22nd January, 1916.	6 months.
Do. .	(145) Mr. C. W. Chater .	Do. .	P. L. .	990	16th February, 1916.	Do.
Do. .	(146) Messrs. H. W. Booth and J. I. Milne.	Do. .	P. L. .	405	14th February, 1916.	1 year.
Do. .	(147) Eu Kya Ban .	Do. .	P. L. .	578	3rd January, 1916.	6 months.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(148) Khoo Zun Ni	All minerals (except oil.)	P. L.	614	28th January, 1916.	6 months.
Do.	(149) Quah Cheng Gwan	Do.	P. L.	640	10th January, 1916.	Do.
Do.	(150) M. A. Sooratee	Do.	P. L.	640	1st February, 1916.	Do.
Do.	(151) Do.	Do.	P. L.	609	17th January, 1916.	Do.
Do.	(152) Messrs. Hitakari & Co.	Do.	P. L.	650	28th February, 1916.	Do.
Do.	(153) Mr. F. G. Fitzherbert.	Do.	P. L.	238	24th February, 1916.	Do.
Do.	(154) S. Merican	Do.	P. L.	400	5th February, 1916	Do.
Do.	(155) San Saing Tin	Do.	P. L.	773	24th February, 1916.	Do.
Do.	(156) Messrs. Balthazar & Son.	Do.	P. L.	1,188	9th January, 1916.	Do.
Do.	(157) Messrs. Hitakari & Co.	Do.	P. L.	573	28th February, 1916.	Do.
Do.	(158) Messrs. Ba Thaung Bros. & Co.	Do	P. L.	737	23rd March, 1916.	Do.
Do.	(159) Messrs. The Bombay Burma Trading Corporation, Ltd.	Do.	P. L.	640	19th February, 1916.	Do.
Do.	(160) Chan Kin Way	Do.	P. L.	750	28th January, 1916.	Do.
Do.	(161) Messrs. Finlay Fleming & Co.	Do.	P. L.	640	16th February, 1916.	Do.
Do.	(162) Messrs. Steel Bros. & Co., Ltd.	Do.	P. L.	640	27th March, 1916.	Do.
Do.	(163) Do.	Do.	P. L.	696	31st January, 1916.	Do.
Do.	(164) Do.	Do.	P. L.	791	Do.	Do.
Do.	(165) Do.	Do.	P. L.	1,116	23rd February, 1916.	Do.
Do	(166) Messrs. Turnbulls (Glasgow), Ltd.	Do.	P. L.	2,409·23	12th January, 1916.	1 year.
Do.	(167) Ong Hoe Kyin	Do.	P. L.	600	25th February, 1916.	6 months
Do.	(168) Mr. G. N. Marks	Do.	P. L.	1,357	26th February, 1916.	Do.
Do.	(169) Do.	Do.	P. L.	1,270	Do.	Do.
Do.	(170) Chan Kin Way	Do.	P. L.	724	22nd February, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term
Tavoy	(171) Messrs. Finlay Fleming & Co.	All minerals (except oil.)	P. L.	825	24th February, 1916.	1 year.
Do.	(172) Messrs. Sein Daing Bros. & Co.	Do.	P. L.	726	23rd February, 1916.	6 months.
Do.	(173) Do.	Do.	P. L.	717	Do.	Do.
Do.	(174) Mr. G. N. Marks	Do.	P. L.	476	26th February, 1916.	Do.
Do.	(175) Mr. F. G. Fitzherbert.	Do.	P. L.	606	29th February, 1916.	Do.
Do.	(176) Messrs. Balthazar & Son.	Do.	P. L.	701	16th March, 1916.	Do.
Do.	(177) Maung Me	Do.	P. L.	687	21st March, 1916.	Do.
Do.	(178) Mahomed Aslam Khan.	Do.	P. L.	392	24th March, 1916.	Do.
Do.	(179) Khoo Tun Byan	Do.	P. L.	322	21st March, 1916.	Do.
Do.	(180) Maung Ni Too	Do.	P. L. (renewal).	1,375	22nd December, 1915.	3 months.
Do.	(181) Kyong Nga	Do.	P. L. (renewal).	2,018	30th January, 1916.	Do.
Do.	(182) Khoo Zun Neo	Do.	P. L.	1,280	7th June, 1916.	6 months.
Do.	(183) Tan Chwan Teow	Do.	P. L.	640	11th June, 1916.	Do.
Do.	(184) The Hon'ble Mr. Lim Chin Tsong.	Do.	P. L.	770	7th June, 1916.	Do.
Do.	(185) Ma Yin Pe	Do.	P. L.	640	20th May, 1916.	Do.
Do.	(186) Kyong Nga	Do.	P. L.	150	19th April, 1916.	Do.
Do.	(187) Messrs. Finlay Fleming & Co.	Do.	P. L.	548	27th June, 1916.	Do.
Do.	(188) Messrs. The Bombay Tavoy Mining Co.	Do.	P. L.	780	9th June, 1916.	Do.
Do.	(189) Messrs. Gillanders Arbuthnot & Co.	Do.	P. L.	760	25th May, 1916.	Do.
Do.	(190) Ma Chein	Do.	P. L.	808	8th May, 1916.	Do.
Do.	(191) Messrs. The Bombay Burma Trading Corporation, Ltd.	Do.	P. L.	1,000	7th June, 1916.	Do.
Do.	(192) Eu Kya Ban	Do.	P. L	580	5th May, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(193) Maung Mya Pe .	All minerals (except oil.)	P. L. .	256	16th June, 1916.	6 months.
Do. .	(194) Mr. H. P. Selvey, Lim Kyer Yau and Ma Sein Daing.	Do. .	P. L. .	575	7th June, 1916.	Do.
Do. .	(195) Messrs. Steel Bros. & Co., Ltd.	Do. .	P. L. .	640	16th May, 1916.	Do.
Do. .	(196) Ong Hoe Kyin .	Do. .	P. L. .	610	29th May, 1916.	Do.
Do. .	(197) C. Soo Don . .	Do. .	P. L. .	610	1st April, 1916.	Do.
Do. .	(198) Messrs. Tata Sons & Co.	Do. .	P. L. .	317	6th June, 1916.	1 year.
Do. .	(199) Ma me . .	Do. .	P. L. .	1,280	4th May, 1916.	6 months.
Do. .	(200) Thi Shwe Zun .	Do. .	P. L. .	842	1st April, 1916.	Do.
Do. .	(201) Mr. A. D. Brown .	Do. .	P. L. .	666	5th April, 1916.	Do.
Do. .	(202) Mr. C. H. Hearsey	Do. .	P. L. .	358	9th June, 1916.	Do.
Do. .	(203) Maung Kyaw .	Do. .	P. L. .	435	19th May, 1916.	Do.
Do. .	(204) Do. .	Do. .	P. L. .	750	Do. .	Do.
Do. .	(205) Messrs. The Bombay Burma Trading Corporation, Ltd.	Do. .	P. L. .	1,360	7th June, 1916.	Do.
Do. .	(206) Messrs. Oosman Musti Khan & Co.	Do. .	P. L. .	2,278	12th April, 1916.	Do.
Do. .	(207) Ong Hoe Kyin .	Do. .	P. L. .	486	21st June, 1916.	Do.
Do.	(208) San Sine Tin .	Do. .	P. L. .	460	16th June, 1916.	Do.
Do. .	(209) Mr. F. H. Jolly .	Do. .	P. L. .	2,073	19th June, 1916.	Do.
Do. .	(210) Ung Kyi Pe .	Do. .	P. L. .	614	17th May, 1916.	Do.
Do.	(211) San Sine Tin .	Do. .	P. L. .	1,172	3rd May, 1916.	Do.
Do. .	(212) A. S. Mahomed .	Do. .	P. L. .	1,894	12th June, 1916.	Do.
Do. .	(213) Messrs. Balthazar & Son.	Do. .	P. L. .	896	22nd June, 1916.	Do.
Do. .	(214) Ong Hoe Kyin .	Do. .	P. L. .	179	13th June, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(215) Mr. S. Crawshaw .	All minerals (except oil).	P. L. .	620	30th June, 1916.	1 year.
Do. .	(216) Maung Po Myee .	Do. .	P. L. .	1,024	1st June, 1916.	6 months.
Do. .	(217) Messrs. Steel Bros. & Co., Ltd.	Do. .	P. L. .	176	Do. .	Do.
Do. .	(218) Ganapat Rai .	Do. .	P. L. .	1,485	19th May, 1916.	Do.
Do. .	(219) Mr. A. E. Wallenberg.	Do. .	P. L. .	720	20th May, 1916.	Do.
Do. .	(220) Ganapat Rai .	Do. .	P. L. .	1,009	13th June, 1916.	Do.
Do. .	(221) Maung Ba Maung	Do. .	P. L. .	512	16th June, 1916.	Do.
Do. .	(222) The Hon'ble Mr. Lim Chin Tsong.	Do. .	P. L. .	222	7th June, 1916.	Do.
Do. .	(223) Khoo Tun Byan .	Do. .	P. L. .	148	30th May, 1916.	Do.
Do. .	(224) Messrs. Steel Bros. & Co., Ltd.	Do. .	P. L. .	1,818	28th June, 1916.	Do.
Do. .	(225) Mahomed Aslam Khan.	Do. .	P. L. .	1,536	26th June, 1916.	Do.
Do. .	(226) San Sine Tin .	Do. .	P. L. .	107	16th June, 1916.	Do.
Do. .	(227) Messrs. Martin and C. dePaulsen.	Do. .	P. L. . (renewal).	766	4th January, 1916.	1 year.
Do. .	(228) Tan Chong Yean .	Do. .	P. L. (renewal).	275	9th February, 1916.	6 months.
Do. .	(229) Messrs. Min Gyaw Bros. & Co.	Do. .	P. L. (renewal).	665	22nd March, 1916.	3 months.
Do. .	(230) Maung Ni Toe .	Do. .	P. L. (renewal).	1,375	Do. .	9 months.
Do. .	(231) Maung Maung .	Do. .	P. L. (renewal).	512	7th April, 1916.	6 months.
Do. .	(232) G. Gyaw Saing .	Do. .	P. L. . (renewal).	6	21st March, 1916.	Do.
Do. .	(233) Kyong Nga . .	Do. .	P. L. (renewal).	2,048	1st May, 1916	9 months.
Do. .	(234) Mr. A. Fraser and Maung Lu Pe.	Do. .	P. L. (renewal).	780	5th December, 1915.	1 year.
Do. .	(235) Khoo Zun Neo .	Do. .	P. L. (renewal).	614	28th January, 1916.	Do.
Do. .	(236) Messrs. The London Rangoon Trading Co., Ltd., and Dr. Douglas, M.D.	Do. .	P. L.	808	1st August, 1916.	6 months.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(237) Messrs. The London Rangoon Trading Co., Ltd., and Dr. Douglas, M.D.	All minerals (except oil).	P. L.	876	1st August 1916.	6 months.
Do.	(238) Eukyong Nga	Do.	P. L.	947	25th July, 1916.	Do.
Do.	(239) Messrs. the London Rangoon Trading Co., Ltd., and Dr. Douglas, M.D.	Do.	P. L.	335	1st August, 1916.	Do.
Do.	(240) Messrs. Lim Kim Seng Bros. & Co.	Do.	P. L.	588	9th August, 1916.	Do.
Do.	(241) Eu Kya Ban and A. G. Frazer.	Do.	P. L.	584	29th June, 1916.	Do.
Do.	(242) Maung Min Gyaw Bros. & Co.	Do.	P. L.	1,182	8th August, 1916.	Do.
Do.	(243) Ma Thin Kyi	Do.	P. L.	600	31st July, 1916.	Do.
Do.	(244) Messrs. Tata Sons & Co.	Do.	P. L.	1,656	5th July, 1916.	Do.
Do.	(245) Mr. A. Rowland H. Ady.	Do.	P. L.	300	6th July, 1916.	Do.
Do.	(246) Maung Po Gywe and Maung E. Kin.	Do.	P. L.	1,100	7th August, 1916.	Do.
Do.	(247) Messrs. Finlay Fleming & Co.	Do.	P. L.	2,990	12th July, 1916.	1 year.
Do.	(248) Mr. S. S. Holkar	Do.	P. L.	1,587	1st July, 1916.	6 months.
Do.	(249) Messrs. Gillanders Arbuthnot & Co.	Do.	P. L.	2,227	6th September, 1916.	Do.
Do.	(250) Khoo Zun Nee	Do.	P. L.	450	2nd August, 1916.	Do.
Do.	(251) Mr. H. G. Mathews	Do.	P. L.	1,434	15th August, 1916.	Do.
Do.	(252) Maung Ba Maung	Do.	P. L.	625	1st July, 1916	Do.
Do.	(253) Chan Kin Way	Do.	P. L.	256	8th July, 1916	Do.
Do.	(254) Mahomed Aslam Khan.	Do.	P. L.	921	4th July, 1916	Do.
Do.	(255) Messrs. The Tavoy Concessions, Ltd.	Do.	P. L.	500	18th July, 1916.	Do.
Do.	(256) Maung Me	Do.	P. L.	1,131	24th July, 1916.	Do.
Do.	(257) Maung Po Htin	Do.	P. L.	594	25th July, 1916.	Do.
Do.	(258) Ma Tin Kyi	Do.	P. L.	578	7th August, 1916.	Do.
Do.	(259) C. Gyaw Saing	Do.	P. L.	1,106	22nd August, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(260) The High Speed Steel Alloys, Ltd.	All minerals (except oil).	P. L. .	1,818	11th September, 1916.	1 year.
Do. .	(261) Do. . .	Do. .	P. L. .	2,301	11th August, 1916.	Do.
Do. .	(262) Do. . .	Do. .	P. L. .	2,202	Do. .	Do.
Do. .	(263) Mr. T. Fowle .	Do. .	P. L. .	450	23rd September, 1916.	6 months.
Do. .	(264) San Sine Tin .	Do. .	P. L. .	911	9th August, 1916.	Do.
Do. .	(265) Mr. J. W. Donaldson Aiken.	Do. .	P. L. .	320	8th August, 1916.	Do.
Do. .	(266) Mr. A. Rowland H. Ady.	Do. .	P. L. .	1,024	2nd August, 1916.	Do.
Do. .	(267) Maung Po Htin .	Do. .	P. L. .	819	15th September, 1916.	Do.
Do. .	(268) Maung Sein Dine .	Do. .	P. L. .	700	23rd September, 1916.	Do.
Do. .	(269) Quah Cheng Gwan	Do. .	P. L. (renewal).	2,400	20th October, 1915.	1 year.
Do. .	(270) Messrs. Hoosain Hamadanee, Robert S. Gibs and Ronald Ady.	Do. .	P. L. (renewal).	765	6th June, 1916.	6 months.
Do. .	(271) Ung Kyi Pe .	Do. .	P. L. (renewal).	279	15th September, 1915.	1 year.
Do. .	(272) Quah Cheng Gwan .	Do. .	P. L. (renewal).	640	10th July, 1916.	6 months.
Do. .	(273) M. A. Soorati .	Do. .	P. L. (renewal).	640	1st August, 1916.	Do.
Do. .	(274) Do. .	Do. .	P. L. (renewal).	609	17th July, 1916.	Do.
Do. .	(275) San Sine Tin .	Do. .	P. L. (renewal).	773	24th August, 1916.	Do.
Do. .	(276) Messrs. Steel Bros. & Co., Ltd.	Do. .	P. L. (renewal).	696	1st August, 1916.	Do.
Do. .	(277) Messrs. Finlay Fleming & Co.	Do. .	P. L. (renewal).	640	16th August, 1916.	Do.
Do. .	(278) Messrs. C. V. Chater.	Do. .	P. L. (renewal).	990	Do	Do
Do. .	(279) Maung Sein Dine Bros. & Co.	Do. .	P. L. (renewal).	717	23rd August, 1916.	Do.
Do. .	(280) Do. .	Do. .	P. L. (renewal).	726	Do. .	Do.
Do. .	(281) Ong Hoe Kyin .	Do. .	P. L. (renewal).	600	25th August, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(282) Osman Musti Khan	All minerals (except oil).	P. L. .	1,700	21st November 1916.	6 months.
Do. .	(283) The High Speed Steel Alloys, Ltd.	Do. .	P. L. .	1,433	13th December, 1916.	Do.
Do. .	(284) Messrs. Steel Bros. & Co., Ltd.	Do. .	P. L. .	2,754	31st October, 1916.	Do.
Do. .	(285) Mr. A. E. Wallenberg.	Do. .	P. L. .	1,422	21st December, 1916.	Do.
Do. .	(286) Maung Po Htin .	Do. .	P. L. .	1,254	7th October, 1916.	Do.
Do. .	(287) Messrs. Finlay Fleming & Co.	Do. .	P. L. .	68	7th July, 1916.	1 year.
Do. .	(288) Mr. S. H. Jolly .	Do. .	P. L. .	680	4th December, 1916.	6 months.
Do. .	(289) Mr. R. C. N. Twite	Do. .	P. L. .	625	14th November, 1916.	Do.
Do. .	(290) San Sine Tin .	Do. .	P. L. .	538	23rd October, 1916.	Do.
Do. .	(291) Thi Shwe Zun .	Do. .	P. L. .	512	20th November, 1916.	Do.
Do. .	(292) M. A. Sooratee .	Do. .	P. L. .	297	4th October, 1916.	Do.
Do. .	(293) Khoo Zun Nee .	Do. .	P. L. .	1,259	4th November, 1916.	Do.
Do. .	(294) M. A. Sooratee .	Do. .	P. L. .	589	27th November, 1916.	Do.
Do. .	(295) Messrs. Finlay Fleming & Co.	Do. .	P. L. .	3,123	1st November, 1916.	Do.
Do. .	(296) Do. .	Do. .	P. L. .	3,200	Do. .	Do.
Do. .	(297) Maung Me . .	Do. .	P. L. .	630	7th October, 1916.	Do.
Do. .	(298) Maung Ba Don .	Do. .	P. L. .	820	4th October, 1916.	Do.
Do. .	(299) Do. .	Do. .	P. L. .	282	11th November, 1916.	Do.
Do. .	(300) Maung Po Myin .	Do. .	P. L. .	435	13th November, 1916.	Do.
Do. .	(301) Maung Po Htin .	Do. .	P. L. .	460	4th October 1916.	Do.
Do. .	(302) Maung E. Zin .	Do. .	P. L. .	120	23rd November, 1916.	Do.
Do. .	(303) Foo Ban Seng and Khoo Zun Nee.	Do. .	P. L. .	1,280	4th November, 1916.	Do.
Do. .	(304) M. A. Sooratee .	Do. .	P. L. .	1,024	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(305) San Sine Tin .	All minerals (except oil)	P. L.	630	5th October, 1916.	6 months
Do. .	(306) C. Soo Don . .	Do. .	P. L. .	604	23rd October, 1916.	Do.
Do. .	(307) Maung Sein Thwe	Do. .	P. L. .	256	9th October, 1916.	Do.
Do .	(308) Maung Ba Don .	Do. .	P. L. .	601	4th October, 1916.	Do.
Do. .	(309) Lim Eng Cheong .	Do. .	P. L. .	1,193	11th November, 1916.	Do.
Do. .	(310) Mr. A. S. Minus .	Do. .	P. L. .	768	27th October, 1916.	Do.
Do. .	(311) Chew Lu Yin .	Do. .	P. L. .	704	6th October, 1916.	Do.
Do. .	(312) Do. .	Do. .	P. L. .	614	3rd October, 1916.	Do.
Do. .	(313) Chew Lu Yin .	Do. .	P. L. .	870	4th November, 1916.	Do.
Do. .	(314) Messrs. Steel Bros. & Co., Ltd.	Do. .	P. L. .	3,200	4th December, 1916.	Do.
Do. .	(315) Messrs. Balthazar & Son.	Do. .	P. L. .	66	19th December, 1916.	Do.
Do. .	(316) Maung Lu Pe .	Do. .	P. L. .	682	1st November, 1916.	Do.
Do. .	(317) Messrs. Hitakari & Co.	Do. .	P. L. .	589	28th November, 1916.	Do.
Do. .	(318) Messrs. The Bombay Burma Trading Corporation, Ltd.	Do. .	P. L. .	1,150	18th November, 1916.	Do.
Do. .	(319) Do. .	Do. .	P. L. .	947	Do.	Do.
Do. .	(320) Eu Kya Ban .	Do. .	P. L. .	282	29th November, 1916.	Do.
Do. .	(321) Maung Po Swe .	Do. .	P. L. .	850	7th December, 1916.	Do.
Do. .	(322) San Sine Tin .	Do. .	P. L. .	445	9th December, 1916.	Do.
Do. .	(323) Mr. G. N. Marks .	Do. .	P. L. .	1,280	27th November, 1916.	Do.
Do. .	(324) Messrs. Finlay Fleming & Co.	Do. .	P. L. .	302	30th November, 1916.	Do.
Do. .	(325) Do. .	Do. .	P. L. .	563	Do.	Do.
Do .	(326) Mr. T. Fowle .	Wolfram . .	P. L. .	320	13th December, 1916.	Do.
Do. .	(327) Maung Maung .	All Minerals (except oil).	P. L. .	896	22nd December, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(328) Maung Pe Myin .	All minerals (except oil).	P. L. .	896	21st December, 1916.	6 months.
Do. .	(329) Maung Sein Kaing	Do. .	P. L. .	910	23rd November, 1916.	Do.
Do. .	(330) Do. .	Do. .	P. L. .	682	Do. .	Do.
Do. .	(331) Maung Maung .	Do. .	P. L. .	640	16th December, 1916.	Do.
Do. .	(332) Maung Shwe Gaing	Do. .	P. L. .	1,229	27th November, 1916.	Do.
Do. .	(333) Ganpat Rai .	Do. .	P. L. .	640	4th December, 1916.	Do.
Do. .	(334) Maung Kya Tun .	Do. .	P. L. .	486	20th November, 1916.	Do.
Do. .	(335) Maung Shwe Gaing	Do. .	P. L. .	1,100	21st December, 1916.	Do.
Do. .	(336) Maung Kya Tun .	Do. .	P. L. .	1,137	27th November, 1916.	Do.
Do. .	(337) Maung Mya Pe .	Do. .	P. L. .	1,306	11th December, 1916.	Do.
Do. .	(338) Ma Me Thu . .	Do. .	P. L. .	1,536	14th December, 1916.	Do.
Do. .	(339) Ma Kya Tun .	Do. .	P. L. .	1,382	4th December, 1916.	Do.
Do. .	(340) Maung Lu Pe .	Do. . .	P. L. .	230	6th December, 1916.	Do.
Do. .	(341) Maung Saw Hlaing	Do. .	P. L. .	1,280	21st December, 1916.	Do.
Do. .	(342) Maung E. Zin .	Do. .	P. L. .	535	19th December, 1916.	Do
Do. .	(343) Ganpat Rai .	Do. .	P. L. .	384	16th December, 1916.	Do.
Do. .	(344) Maung Me . .	Do. .	P. L. .	1,280	22nd December, 1916.	Do.
Do. .	(345) Chan Kin Way .	Do. .	P. L. (renewal).	371	26th July, 1916.	Do.
Do. .	(346) Mr. S. Merican .	Do.	P. L. (renewal).	599	5th August, 1916.	Do.
Do. .	(347) Tan Chwan Teow for the late Tan Cheong Yean.	Do.	P. L. (renewal).	275	9th August, 1916.	3 months.
Do. .	(348) Ong Hoe Kyin .	Do. .	P. L. (renewal).	600	25th August, 1916.	6 months.
Do. .	(349) Lim Shein . .	Do. .	P. L. (renewal).	1,000	2nd September, 1916.	1 year.
Do .	(350) Mr. F. G. Fitzherbert.	Do.	P. L. (renewal).	238	24th August, 1916.	6 months.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(351) Mr. G. N. Marks .	All minerals (except oil)	P. L. (renewal).	476	26th August, 1916.	6 months.
Do. .	(352) Khoo Tun Byan .	Do. .	P. L. (renewal).	322	21st September, 1916.	Do.
Do. .	(353) Mahomed Aslam Khan.	Do. .	P. L. (renewal).	392	24th September, 1916	Do.
Do. .	(354) Messrs. Osman Musti Khan & Co.	Do. .	P. L. (renewal).	2,278	12th October, 1916	Do.
Do. .	(355) Messrs. Balthazar & Son.	Do .	P. L. (renewal).	701	16th September, 1916.	Do.
Do .	(356) Lim Kyee Yan .	Do. .	P. L. (renewal).	161·28	28th September, 1916.	1 year.
Do. .	(357) Mr. H. P. Selvey, Lim Kyee Yan and Ma Sein Daing.	Do. .	P. L. (renewal).	574	Do. .	Do.
Do. .	(358) Thi Shwe Zun .	Do. .	P. L. (renewal).	842	1st October, 1916.	6 months.
Do. .	(359) Messrs. Ba Thaung Bros. & Co.	Do. .	P. L. (renewal)	737	23rd September, 1916.	Do.
Do. .	(360) Ong Hoe Kyin .	Do. .	P. L. (renewal).	605	4th October, 1916.	3 months.
Do. .	(361) Maung Maung .	Do. .	P. L. (renewal).	512	7th October, 1916.	1 year.
Do .	(362) Mr. A. D. Brown .	Do. .	P. L. (renewal).	666	5th October, 1916.	6 months
Do. .	(363) Messrs. Steel Bros. & Co., Ltd.	Do. .	P. L. (renewal).	640	27th September, 1916	Do.
Do. .	(364) Eu Kyong Nga .	Do. .	P. L. (renewal).	450	19th October, 1916.	Do.
Do. .	(365) Maung Ni . .	Do. .	P. L. (renewal),	1,071	11th September, 1916.	Do.
Do. . .	(366) San Sine Tin .	Do. .	P. L. (renewal).	1,172	3rd November, 1916.	Do.
Do. .	(367) Ung Kyi Pe .	Do. .	P. L. (renewal).	614	17th November, 1916.	Do.
Do. .	(368) Khoo Tun Byan .	Do. .	P. L. (renewal).	148	30th November, 1916.	Do.
Do. .	(369) Eu Kya Ban .	Do. .	P. L. (renewal).	580	5th November, 1916.	Do.
Do. .	(370) Maung Po Myee .	Do. .	P. L. (renewal).	1,024	1st December, 1916.	Do.
Do. .	(371) Ong Hoe Kyin .	Do. .	P. L. (renewal).	610	29th November, 1916.	Do.
Thaton .	(372) Maung Pan Dwe .	Do. .	P. L. .	2,547·2	10th February, 1916.	1 year.

P. L.—*Prospecting License.* M. L.—*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thaton .	(373) C. Soo Don . .	All minerals (except oil).	P. L. .	1,830·4	2nd February, 1916.	1 year.
Do. .	(374) Ma Them Zin .	Do. .	P. L. .	320	Do. .	Do.
Do. .	(375) M. Ah Khee .	Do. .	P. L. .	467·2	Do. .	Do.
Do. .	(376) The Hon'ble Mr. Lim Chin Tsong.	Do. .	P. L. .	953·6	14th February, 1916.	Do.
Do. .	(377) Maung Kaing	Do. .	P. L. .	844·8	Do. .	Do.
Do. .	(378) U Ba Wet .	Do. .	P. L. .	1,203·2	2nd February, 1916.	Do.
Do. .	(379) Mr. H. E. Singleton	Do. .	P. L. .	1,657·6	21st February, 1916.	Do.
Do. .	(380) C. H. Stork . .	Do. .	P. L. .	672	17th February, 1916.	Do.
Do. .	(381) Mr. A. J. Salvador	Do. .	P. L. .	851·2	7th April, 1916.	Do.
Do. .	(382) Maung Thwin .	Do. .	P. L. .	1,446·4	10th April, 1916.	Do.
Do. .	(383) Ma Chit Su . .	Do. .	P. L. .	1,395·2	11th May, 1916.	Do.
Do. .	(384) Maung Chit Maung	Do. .	P. L. .	1,836·8	11th April, 1916.	Do.
Do. .	(385) Maung On Pe .	Do. .	P. L. .	1,350·4	12th April, 1916.	Do.
Do. .	(386) Maung San Hain .	Do. .	P. L. .	947·2	6th April, 1916.	Do.
Do. .	(387) Maung Pu . .	Do. .	P. L. .	108·8	7th April, 1916.	Do.
Do. .	(388) M. A. Kadar .	Do. .	P. L. .	499·2	1st April, 1916.	Do.
Do. .	(389) C. Soo Don . .	Do. .	P. L. .	876·8	18th May, 1916.	Do.
Do. .	(390) U Pan Dwe . .	Do. .	P. L. .	2,649·6	17th April, 1916.	Do.
Do. .	(391) U Po Tha . .	Do. .	P. L. .	108·8	9th June, 1916.	Do.
Do. .	(392) Mr. C. H. Stork .	Do. .	P. L. .	819·2	17th August, 1916.	6 months.
Do.	(393) U Ba Wet . .	Do. .	P. L. .	1,190·4	Do. .	1 year.
Do. .	(394) Maung San Hain .	Do. .	P. L. .	115·2	20th October, 1916.	Do.
Do.	(395) Mr. F. A. Boog .	Do. .	P. L. .	1,376	28th November, 1916.	Do.
Do.	(396) Ong Po Hein .	Do. .	P. L. .	473·6	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thayetmyo	(397) Messrs. The British Burma Petroleum Co., Ltd.	Mineral oil	P. L.	94·72	23rd December, 1915.	1 year.
Do.	(398) Messrs. The Burma Oil Co., Ltd.	Do.	P. L.	1,920	17th August, 1916.	Do.
Do.	(399) Do.	Do.	P. L. (renewal).	4,480	19th April, 1916.	Do.
Do.	(400) Do.	Do.	P. L.	960	13th September, 1916.	Do.
Do.	(401) Do.	Do.	P. L. (renewal).	1,410	28th August, 1916.	Do.
Do.	(402) Do.	Do.	P. L. (renewal).	3,840	24th September, 1916.	Do.

CENTRAL PROVINCES.

Balaghat	(403) Babu Kripashankar	Manganese	P. L	272	5th February, 1916.	1 year.
Do.	(404) Tata Iron and Steel Co., Ltd.	Do.	M. L.	48	29th November, 1915.	30 years.
Do.	(405) Mr. T. D Ram Chandra Naidu.	Do.	P. L.	200	27th January, 1916.	1 year.
Do.	(406) Babu Kripashankar	Do.	M. L.	155	25th January, 1916.	30 years.
Do.	(407) Messrs. Ramprasad and Lakshminarayan.	Do.	P. L.	3	7th March, 1916.	1 year.
Do.	(408) Khan Bahadur Byramji Pestonji.	Do.	P. L.	187	27th January, 1916.	Do.
Do.	(409) Mr. A. C. Blechynden.	Mica	P. L.	105	14th March, 1916.	Do.
Do.	(410) Tata Iron and Steel Co., Ltd.	Manganese	P. L.	3	22nd February, 1916.	Do.
Do.	(411) Babu Kripashankar	Do.	P. L.	164	5th February, 1916.	Do.
Do.	(412) Khan Bahadur Byramji Pestonji.	Do.	P. L.	604	27th January, 1916.	Do.
Do.	(413) Babu Kripashankar	Do.	P. L.	340	14th June, 1916.	Do.
Do.	(414) Messrs. Tata Iron and Steel Co., Ltd.	Do.	M. L.	149	26th May, 1916.	30 years.
Do.	(415) Pundit Rewashankar.	Do.	P. L.	48	7th April, 1916.	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(416) Hon'ble Diwan Bahadur Sir Kasturchand Daga, K.C.I.E	Manganese . .	P. L. .	15	23rd June, 1916.	1 year.
Do. .	(417) Pundit Rewashankar.	Do. . .	P. L. .	80	28th April, 1916.	Do.
Do. .	(418) Do. .	Do. . .	P. L. (renewal).	72	7th June, 1915.	6 months.
Do. .	(419) Babu Kripashankar	Do. .	P. L. (renewal).	118	25th June, 1915.	Do.
Do. .	(420) Do. .	Do. . .	P. L. (renewal).	376	8th July, 1916	Do.
Do. .	(421) Messrs. Ferozsha Bahmansha Fouzdar Brothers.	Do. . .	M. L. .	60	17th July, 1916.	10 years.
Do. .	(422) Khan Bahadur Byramji Pestonji.	Do. . .	M. L. .	1	22nd June, 1916.	5 years.
Do. .	(423) Babu Kripashankar	Do . .	P. L. .	64	29th August, 1916.	1 year.
Do. .	(424) Mr. A. C. Blechynden.	Mica . .	P. L. .	124	24th July, 1916.	Do.
Do. .	(425) Babu Kripashankar	Manganese . .	M. L. .	51	15th August, 1916.	5 years.
Do. .	(426) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	27	29th August, 1916.	1 year.
Do. .	(427) Mr. S. Lakshman Rao Naidu.	Do. . .	P. L. .	48	24th October, 1916.	Do.
Do. .	(428) Mr. D. W. A. MacDonald.	Bauxite . .	M. L .	38	18th October, 1916.	30 years.
Do. .	(429) Babu Kripashankar	Manganese . .	M. L. .	31	31st October, 1916.	Do
Do. .	(430) Pundit Rewashankar.	Do. . .	P. L. .	41	17th November, 1916.	1 year.
Do.	(431) Messrs. Goredutt, Ganeshlal and M. D'Costa.	Do. . .	P. L.	445	Do. .	Do.
Bhandara .	(432) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	101	8th January, 1916.	Do.
Do. .	(433) Seth Gowardhandas.	Do. . .	M. L. .	18	2nd February, 1916.	30 years
Do. .	(434) Khan Bahadur Byramji Pestonji.	Do. . .	P. L.	10	8th January, 1916.	1 year.
Do. .	(435) Messrs. Goredutt, Ganeshlal and M. D'Costa.	Do. . .	P. L.	5	31st March, 1916.	Do.
Do. .	(436) Messrs. Lalbehari and Ramcharan.	Do. . .	P. L. (renewal).	2	4th December, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara .	(437) Seth Mahadeo .	Manganese . .	P. L. (renewal).	314	10th March, 1916.	6 months.
Do. .	(438) Seth Gowardhandas.	Do. . .	P. L. .	39	21st March, 1916.	1 year.
Do. .	(439) Do. .	Do. . .	P. L. (renewal).	29	6th February, 1916.	6 months.
Do. .	(440) Messrs. Goredutt, Ganeshlal and M. D'costa.	Do. . .	P. L. .	142	31st March, 1916.	1 year.
Do. .	(441) Mr. T. D. Ramchandra Naidu.	Do. . .	M. L. .	28	21st March, 1916.	10 years.
Do. .	(442) Seth Mahadeo .	Do. . .	P. L. .	38	15th June, 1916.	1 year.
Do. .	(443) Seth Goverdhan Das.	Do. . .	M. L. .	68	5th March, 1916.	30 years.
Do. .	(444) Indian Manganese Co., Ltd.	Do. . .	P. L. .	78	13th May, 1916.	1 year.
Do. .	(445) Khan Bahadur Byramji Pestonji.	Do. . .	P. L. .	21	17th June, 1916.	Do.
Do. .	(446) Messrs. Lalbehari and Ramcharan.	Do. . .	P. L. .	16	11th July, 1916.	Do.
Do. .	(447) Seth Mahadeo .	Do. . .	M. L. .	24	11th June, 1916.	30 years.
Do. .	(448) Do. .	Do. . .	P. L. .	8	26th September, 1916.	1 year.
Do. .	(449) Do. .	Do. . .	P. L. .	30	27th August, 1916.	Do.
Do. .	(450) Messrs. Goredutt, Ganeshlal and M. D'Costa.	Do. . .	P. L. .	69	18th July, 1916.	Do.
Do. .	(451) Do. .	Do. . .	P. L. .	13	16th September, 1916	Do.
Do. .	(452) Seth Mahadeo .	Do. . .	P. L. . (renewal).	314	10th September, 1916.	6 months.
Do. .	(453) Do. .	Do. . .	M. L. .	57	6th September, 1916.	30 years.
Do. .	(454) Do. .	Do. . .	M. L. .	602	Do. .	Do.
Do. .	(455) Setth Gowardhandas.	Do. . .	M. L. .	15	10th November, 1916.	10 years.
Do. .	(456) Messrs. Lalbehari and Ramcharan.	Do. . .	P. L. .	3	20th December, 1916.	1 year.
Do. .	(457) Seth Gowardhandas	Do. . .	P. L. .	139	16th November, 1916.	Do.
Do. .	(458) Seth Mahadeo .	Do. . .	P. L. .	92	Do.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara .	(459) Messrs. Lalbehari and Ramcharan.	Manganese . .	P. L. (renewal).	2	4th December, 1916.	1 year.
Betul .	(460) Hon'ble Mr. M. R. Dikshit.	Lead and Graphite	P. L. .	2,177	18th November, 1916.	Do.
Do. .	(461) Shaikh Shahabuddin.	Graphite. . .	P. L. .	256	22nd November, 1916.	Do.
Chanda .	(462) Mulla Hasanali Nathubhoy.	Coal . . .	M. L. .	792	13th December, 1915.	Will expire with the original lease dated the 15th January 1915, to which it is supplementary.
Do. .	(463) Messrs. H. Verma and Kanhaiyalal.	Do. . . .	P. L. .	569	22nd June, 1916.	1 year.
Do. .	(464) Chanda Coal Prospecting Syndicate, Ltd.	Do. . .	P. L. .	618	1st June, 1916.	Do.
Do. .	(465) Hon'ble Mr. M. B. Dadabhoy, C.I.E	Do. . .	P. L. .	1,188	3rd August, 1916.	Do.
Do. .	(466) Mulla Hasan Ali Nathubhoy.	Do. . .	M. L. .	143	13th November, 1916.	30 years.
Chhindwara	(467) Messrs. Shaw, Wallace & Co., Pench Valley Coal Co., Ltd.	Do. . .	M. L .	60	31st January, 1916.	Do.
Do. .	(468) Hon'ble Diwan Bahadur Sir Kasturchand Daga, K.C.I.E.	Manganese . .	M. L. .	142	17th April, 1916.	5 years.
Do. .	(469) Messrs. H. Verma and Kanhaiyalal.	Coal . . .	M. L. .	324	7th June, 1916.	30 years.
Do. .	(470) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Manganese .	P. L. .	85	1st April, 1916.	1 year.
Do. .	(471) Messrs. H. Verma and Kanhaiyalal.	Coal . . .	P. L. .	253	24th May, 1916.	Do.
Do. .	(472) Messrs. Shaw, Wallace & Co.	Do. . . .	M. L. .	114	8th November, 1916.	30 years.
Do. .	(473) Diwan Bahadur Sir Kasturchand Daga K.C.I.E.	Manganese . .	P. L. (renewal).	172	5th November, 1916.	1 year.
Nagpur .	(474) Central India Mining Co., Ltd.	Galena . .	P. L. .	538	16th February, 1916.	Do.
Do. .	(475) Messrs. Goredutt, Ganeshlal and M. D'Costa.	Manganese . .	M. L. .	26	20th December, 1915.	5 years.
Do. .	(476) Hon'ble Diwan Bahadur Sir Kasturchand Daga, K.C.I.E.	Do. . .	P. L. .	133	13th January, 1916.	1 year.

P. L.=*Prospecting License* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement	Term.
Nagpur	(477) Central Provinces Prospecting Syndicate, Ltd.	Manganese	M. L.	1	13th March, 1916.	Will expire with the original lease, dated the 31st July 1901 to which it is supplementary.
Do.	(478) Central India Mining Co., Ltd.	Do.	M. L.	2	19th April, 1916	Will expire with the original lease dated 7th February 1906, to which it is supplementary.
Do.	(479) Messrs. Goredutt, Ganeshlal and M D'Costa.	Do	P. L.	146	7th April, 1916	1 year.
Do.	(480) Mr. Asaram Chandrabhan	Do.	P. L.	285	30th May, 1916	Do.
Do.	(481) Messrs Goredutt, Ganeshlal and M D'Costa.	Do	P. L.	85	13th May, 1916.	Do.
Do.	(482) Central Provinces Prospecting Syndicate, Ltd.	Do.	M. L.	5	10th April, 1916.	Will expire with the original lease, dated the 31st July 1901, to which it is supplementary.
Do.	(483) Hon'ble Mr. M B Dadabhoy, C I E	Do.	P. L.	30	1st June, 1916.	1 year.
Do.	(484) Messrs. Goredutt, Ganeshlal and M. D'Costa.	Do	P. L.	163	7th May, 1916.	Do.
Do.	(485) Nagpur Manganese Mining Syndicate.	Do.	M. L.	12	2nd August, 1916.	5 years.
Do.	(486) Messrs. Lalbehari and Ramcharan.	Do.	P. L.	72	13th July, 1916	1 year
Do.	(487) Hon'ble Mr. M B. Dadabhoy, C.I.E.	Do.	P. L. (renewal)	297	16th September 1916	Do
Do.	(488) Messrs. Ramprasad and Lakshminarayan.	Do.	P. L. (renewal)	168	11th October, 1916	Do.
Do.	(489) Indian Manganese Co., Ltd.	Do.	P. L.	21	19th December, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*concld.*

DISTRICT.	Grantee	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(490) Central India Mining Co, Ltd.	Manganese . .	M. L. .	1	27th November, 1916.	Will expire with the original lease, dated the 17th January 1905, to which it is supplementary.
Do. .	(491) Rai Bahadur Bansilal Abirchand Mining Syndicate.	Do. . . .	P. L. (renewal).	147	9th October, 1916.	1 year.
Do .	(492) Khan Bahadur Byramji Pestonji.	Do. . . .	P. L. .	108	22nd December, 1916.	Do.
Narsinghpur	(493) Diwan Bahadur Seth Ballabhdas, Mannoolal and Kanhaiyalal.	Coal	P. L. .	140	7th September, 1916.	Do.
Raipur .	(494) Mr Moreshwar Rajaram Dixit	Graphite (plumbago).	P. L. .	351	5th September, 1916	Do.
Do. .	(495) Devi Prasad Bania	Copper . . .	P. L .	586	20th December, 1916	Do.

MADRAS.

DISTRICT.	Grantee	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kurnool .	(496) Mr. H. M. A. Cooke, Esq., Superintendent, the Ooregaum Gold Mining Co., Ltd., Ooregaum, Mysore Province.	Gold, Diamonds and copper.	P. L. .	369·52	30th December, 1915.	1 year.
Do. .	(497) A. Ghose, Esq. .	Barytes . .	P. L. .	33·05	29th July, 1916.	Do.
Do. .	(498) Mr. H. M. A. Cooke, Esq., Superintendent, Ooregaum Gold Mining Co., Ltd., Ooregaum.	Gold, Diamonds and copper.	P. L. .	52·74	25th August, 1916.	Do.
Nellore .	(499) P. K. Vengama Nayudu.	Mica	P. L. .	22·84	13th January, 1916.	Do.
Do. .	(500) K. Venkataramanayya.	Do.	P. L. .	15·00	6th March, 1916.	Do.
Do. .	(501) Messrs. F. F. Chrestien & Co.	Do.	P. L. .	45·78	9th November, 1915.	Do.
Do. .	(502) The South Indian Export Co.	Do.	M. L. .	30·35	1st January, 1916.	30 years.
Do. .	(503) Messrs. F. F. Chrestien & Co.	Do.	P. L. .	2·32	1st March, 1916.	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

MADRAS—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore	(504) Messrs F. F. Chrestien & Co.	Mica	P. L	10·00	1st March, 1916	1 year.
Do.	(505) Sri Vasi Reddi Chandramouleshwara Prasad Bahadur.	Do.	P. L.	8·61	19th October, 1915.	Do.
Do.	(506) K. Penchalu Reddi	Do.	P. L.	20·87	15th April, 1916.	Do.
Do.	(507) K. Venkatasubbiah	Do.	P. L.	44·75	Do.	Do.
Do.	(508) Messrs. F F. Chrestien & Co.	Do.	P. L.	115·73	1st May, 1916	Do
Do.	(509) K. Venkatasubbiah	Do.	P. L.	14·98	15th April, 1916	Do.
Do	(510) Moolji Govindji	Do	P. L.	20·00	1st June, 1916.	Do.
Do.	(511) Khan Bahadur Muhammad Safdar Hussain Khan Sahib.	Do.	P. L.	16·85	1st September, 1916.	Do.
Do.	(512) N. Raghavalu Naikar.	Do.	P L.	9 41	1st July, 1916	Do.
Do.	(513) Kandamer Ramachandriah	Do.	M L	76 65	3rd October, 1916.	30 years.
Do.	(514) K. Venkataramaniah.	Do.	P. L.	26 46	20th October, 1916.	1 year.
Do.	(515) Messrs. F. F. Chrestien & Co.	Do.	P. L.	83·90	14th August, 1916.	Do.
Do.	(516) N. Raghavalu Nayakar.	Do.	P. L	37·40	18th November, 1916.	Do
South Canara	(517) Mr. Timothy Pinto	Garnet	P. L.	1·37	9th November, 1916.	Do.
Trichinopoly	(518) Messrs. T. Stanes & Co.	Phosphatic nodules	P. L.	172 90	6th October, 1916.	Do.

PUNJAB.

Attock	(519) Burma Oil Co.	Mineral oil	P. L.	5,440	17th March, 1916.	1 year.
Do.	(520) Do.	Do.	P. L.	1,080	Do.	Do.
Do.	(521) Do.	Do.	P. L.	3,520	Do.	Do.
Do.	(522) Do.	Do.	P. L.	800	Do.	Do.
Do.	(523) Do.	Do.	P. L.	294·4	15th August, 1916.	Do.
Do.	(524) Do.	Do.	P. L.	1,400	25th September, 1916.	Do.
Jhelum	(525) Lala Thakur Das and Lala Ramji Das.	Coal	M. L.	755·75	11th September, 1911.	30 years.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

PUNJAB—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement	Term.
Jhelum	(526) Lala Ishar Das	Coal	M. L.	151 5	24th January, 1913.	15 years.
Do.	(527) Burma Oil Co, Ltd. (Scotland).	Mineral Oil	P. L.	1,920	12th April, 1916	1 year.
Do.	(528) Indo-Burma Petroleum Co., Ltd., Rangoon.	Do.	P. L.	3,840	23rd June, 1916.	Do.
Do.	(529) Do.	Do.	P. L.	3,520	Do.	Do
Do.	(530) Messrs Thakur Das, Ramji Das and Ishar Das.	Coal	M. L.	370	11th September, 1911.	15 years.
Do.	(531) Lala Ishar Das	Do.	M. L	225	11th September, 1912.	Do.
Do.	(532) Do	Do.	M L	81 5	22nd May, 1916.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

SUMMARY.

Province.	Prospecting Licenses.	Mining Leases.	Total of each Province.
Assam	5	..	5
Baluchistan	2	9	11
Bihar and Orissa	24	6	30
Bombay	2	..	2
Burma	353	1	354
Central Provinces	66	27	93
Madras	21	2	23
Punjab	9	5	14
Total of each kind and Grand Total 1916.	482	50	532
TOTAL OF 1915	261	46	307

CLASSIFICATION OF LICENSES AND LEASES.

TABLE 36.—*Prospecting Licenses granted in Assam during 1916.*

DISTRICT.	1916.		
	No.	Area in acres.	Mineral.
Cachar	1	3,180·8	Oil.
Khasi and Jaintia Hills	1	12,704	Gold and certain other allied minerals.
Do.	1	12,704	Tin and wolfram.
Do.	1	8,160	Gold, tin and certain other allied minerals.
Lakhimpur	1	25,600	Coal, oil, iron, slate and shales.
TOTAL	5	..	

TABLE 37.—*Prospecting Licenses and Mining Leases granted in Baluchistan during 1916.*

DISTRICT.	1916.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Kalat	1	24,960	Oil.
Quetta Pishin	1	80	Chrome.
TOTAL	2	..	
Mining Leases.			
Kalat	2	160	Coal.
Quetta Pishin	1	160	Chrome.
Sibi	1	80	Coal.
Zhob	5	3,143	Chromite.
TOTAL	9	..	

TABLE 38.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during 1916.*

DISTRICT.	1916.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Hazaribagh	1	310	Mica.
Singhbhum	4	3,242·06	Manganese.
Do.	1	320	Gold, manganese and bauxite.
Do.	3	451·52	Chromite and associated minerals.
Do.	7	5,592·28	Chromite.
Do. . . .	4	4,320	Iron, chromite, manganese, tungsten, gold, galena and allied minerals.
Do. . . .	1	990	Manganese and iron ore.
Do.	2	10,115·2	Iron ore.
Do.	1	3,200	Iron, chromite, manganese, wolfram, galena and allied ores.
TOTAL .	24	..	
Mining Leases.			
Singhbhum	2	82·84	Chromite.
Do.	2	9·60	Yellow ochre.
Do.	1	1·6	Red ochre.
Do.	1	240	Manganese.
TOTAL .	6	..	

TABLE 39.—*Prospecting Licenses granted in Bombay during 1916.*

DISTRICT.	1916.		
	No.	Area in acres.	Mineral.
Panch Mahals . . .	2	552·3	Manganese.

TABLE 40.—*Prospecting Licenses and Mining Leases granted in Burma during 1916.*

DISTRICTS.	1916.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Akyab	1	5,440	Mineral oil.
Amherst	21	16,501	All minerals except oil.
Do.	1	960	Gold, silver, copper, wolfram and antimony.
Do.	1	640	Tin, wolfram, lead, gold, copper, silver and antimony.
Do.	1	50	Graphite.
Katha	1	24,320	Tin, wolfram, silver, copper, lead, zinc and gold.
Do.	1	4,800	Tin, wolfram, silver and copper.
Do.	1	960	Zinc, lead and silver.
Kyaukpyu	1	2,105·6	Mineral oil.
Lower Chindwin	3	2,940	All minerals (except oil).
Do.	1	1,440	Copper.
Do.	1	960	Mineral oil.
Magwe	1	3,840	Do.
Mandalay	1	2,560	All minerals (except oil).
Mergui	21	25,442·33	Do.
Do.	1	1,330	Tin and wolfram.
Minbu	6	2,828·72	Mineral oil.
Myingyan	1	2,813·3	Do.
Myitkyina	1	3,200	Gold and irido-platinum.
Do.	1	640	Gold.
Northern Shan States	1	3,200	Gold, silver, lead, iron and zinc.
Pakokku	6	16,911·03	Mineral oil.
Prome	2	6,400	Do.
Shwebo	1	7,040	Do.
Southern Shan States	1	640	Mica.
Do. do.	4	4,773·90	Wolfram.
Do. do.	9	16,645	All minerals (except oil).
Do. do.	1	640	Lead.
Do. do.	1	3,200	Gold, galena, copper, tin and wolfram.
Do. do.	1	640	Antimony and associated minerals except oil.
Tavoy	227	195,962·51	All minerals (except oil)
Do.	1	320	Wolfram.
Thaton	25	26,540·8	Do.
Thayetmyo	6	12,734·72	Mineral oil.
TOTAL	353	..	

TABLE 40.—*Prospecting Licenses and Mining Leases granted in Burma during 1916*—contd.

DISTRICTS.	1916. No.	1916. Area in acres.	1916. Mineral.
Mining Leases.			
Minbu .		501	Mineral oil.

TABLE 41.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1916.*

DISTRICTS.	1916. No.	1916. Area in acres.	1916. Mineral.
Prospecting Licenses.			
Balaghat	19	3,107	Manganese.
Do.	2	229	Mica.
Bhandara	21	1,465	Manganese.
Betul	1	2,177	Lead and graphite.
Do.	1	256	Graphite.
Chanda	3	2,375	Coal.
Chhindwara	2	257	Manganese.
Do.	1	253	Coal.
Nagpur	1	538	Galena.
Do.	12	1,656	Manganese.
Narsinghpur	1	140	Coal.
Raipur	1	351	Graphite.
Do.	1	586	Copper.
TOTAL .	66	..	
Mining Leases.			
Balaghat	7	495	Manganese.
Do.	1	38	Bauxite.
Bhandara	7	812	Manganese.
Chanda	2	935	Coal.
Chhindwara	3	498	Do.
Do.	1	142	Manganese.
Nagpur	6	47	Do.
TOTAL .	27	..	

TABLE 42.—*Prospecting Licenses and Mining Leases granted in Madras during 1916.*

DISTRICTS.	1916.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Kurnool	2	422·26	Gold, diamonds and copper.
Do.	1	33·05	Barytes.
Nellore	16	494·90	Mica.
South Canara	1	1·37	Garnet.
Trichinopoly	1	172·90	Phosphatic nodules.
TOTAL	21	..	
Mining Leases.			
Nellore	2	107	Mica.

TABLE 43.—*Prospecting Licenses and Mining Leases granted in the Punjab during 1916.*

DISTRICTS.	1916.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Attock	6	12,534·4	Mineral oil.
Jhelum	3	9,280	Do.
TOTAL	9		
Mining Leases.			
Jhelum	5	1,583·75	Coal.

PRELIMINARY NOTE ON SOME RECENT MAMMAL COLLECTIONS FROM THE BASAL BEDS OF THE SIWALIKS. BY LIEUT. G. E. PILGRIM, D.SC., I.A.R.O., *Assistant Superintendent, Geological Survey of India.*

JUST before I withdrew temporarily from scientific research in May 1915, the cold season's geological work in two distinct areas containing ossiferous deposits was concluded and the respective investigators returned each with an interesting collection of mammalian fossils which I had the opportunity, though a limited one, of examining and discussing with the collectors. One of these geologists was Mr. E. S. Pinfold of the Indo-Burma Petroleum Company, who had been working in the country north of the Salt Range, and the others were Messrs. M. Vinayak Rao, and Bankim Behari Gupta, both of the Geological Survey of India, who had been engaged respectively in stratigraphical and collecting work in Sind.

It chances that the collections are complementary to, and mutually explanatory of, one another and throw some interesting light on the correlation of the basal deposits of the Siwaliks. Although the author must needs defer their complete investigation until a future occasion, it seems wise, especially in view of the special circumstances which necessitate the interruption of the work to place on record certain important results, which already stand out clearly. These both afford a confirmation of the author's previous views[1] as to the classification of the basal beds of the Siwaliks, but at the same time render a revision of the nomenclature adopted by him in 1913 almost obligatory.

In the paper quoted I put forward strong presumptive evidence that the 1,700 feet or so of non-fossiliferous strata, which occur in the Salt Range below the Chinji zone, are the equivalent of the lowest beds of the Siwalik series in Sind from which Blanford and Fedden had obtained mammalian fossils some 30 years ago. The Tertiary fluviatile formation of Sind, later referred to the Siwaliks, was divided by Blanford into Upper and Lower Manchhars and since the only fossils found so far were those mentioned above, which

[1] G. E. Pilgrim: Correlation of the Siwaliks with the Mammal Horizons of Europe; *Rec. Geol. Surv. Ind.*, XLIII, part 4 (1913).

came near the base of the series, I adopted the name Lower Manchhar as that of a zone in which I included also the 1,700 feet of deposits below the Chinji zone of the Salt Range. At the time it seemed likely that, if not the Chinji horizon, at all events the Middle Siwaliks, were missing. This we now know not to be the case.

Some very thorough and admirable collecting near Bhagathoro in Sind by Babu Bankim Behari Gupta has revealed at least three distinct horizons in Blanford's Lower Manchhars:—

1. A basal one with *Tetrabelodon angustidens* var. *palæindicus*, *Hyoboops palæindicus*, and other species unknown in the Chinji beds.
2. A higher one with Chinji fossils.
3. A still higher one with fossils of the Dhok Pathan zone.

Above this come the series of coarse conglomerates and boulder-beds, called by Blanford Upper Manchhars; these though distributed over a wide area, do not appear to attain any great thickness. Some badly preserved fossils found in these by Babu Bankim Behari Gupta serve to confirm the opinion induced by their lithological character, that the Upper Manchhars belong to the Upper Siwaliks and probably to the uppermost portion of that division.

In these circumstances it is obviously impossible to retain the name Lower Manchhar for a particular zone in the Lower Siwaliks. Mr. Pinfold not only provides us with an appropriate name for the basal zone, but at the same time furnishes us with the much needed evidence for correlating the beds beneath the Chinji horizon in the Salt Range with those at the base of the Siwalik formation in Sind.

I am unable to reproduce a section to illustrate Mr. Pinfold's stratigraphical work. This omission he himself will no doubt remedy when he amplifies this meagre account elsewhere. Suffice it to say that on the northern side of the Sohan river going towards the Khaire Murat ridge, on the southern slopes of a well-marked anticlinal fold a passage has been found from the Middle Siwaliks, through beds, which Mr. Pinfold assigns to the Chinji zone and which contain a few Chinji fossils, to a lower zone, near the village of Kamlial, which contains certain species identical with those found in the basal beds of the Lower Manchhar series of Sind. These Mr. Pinfold has named the Kamlial beds and I cannot do better than adopt this, the only locality so far known in the Salt Range where this horizon is fossiliferous, as the name of the zone. Thus both the basal beds of the Siwalik series in Sind in the Bugti Hills

and on the northern slopes of the Salt Range below the Chinji beds will be included in the "Kamlial zone."

Of the numerous specimens collected by Messrs. Vinayak Rao and Bankim Behari Gupta I had only time to submit a few to anything like a detailed examination, but this was enough to enable me to arrive at definite conclusions on the following points—

(1) the species *Hyotherium sindiense* founded by Lydekker on some molar teeth is shown by the character of its premolars to be undoubtedly distinct from the Chinji *Hyotherium*, which hitherto I had been content to refer to as *Hyotherium* cf. *sindiense*. This should now receive another name which may be *Hyotherium chinjiense*. A mandible of this species was figured in the author's paper on "The dentition of the new Creodont genus *Dissopsalis*" (*Rec., Geol. Surv. Ind.*, XLIV, pt. 4, text fig. 13);

(2) a species of *Listriodon* occurs at Bhagathoro in Sind which is clearly different from *Listriodon pentapotamiæ* of Chinji. It shows a curious tendency towards the bunodont species of the Sables de l'Orléanais, *Listriodon Lockharti*, and apparently represents an intermediate stage in the completion of the transverse crests;

(3) a species of *Dorcabune*, smaller and more primitive than any of the Chinji forms has been described and figured in the author's paper on "*Dorcabune*, a new Tragulid genus" (*Rec., Geol. Surv. Ind.*, XLV, pt. 3). It seems to be fairly abundant in the basal zone:

(4) numerous specimens of *Tetrabelodon angustidens* var. *palæindicus* are identical with those found in a corresponding zone of the Lower Siwaliks in the Bugti Hills. This species has not so far been found in the Chinji zone.

A partial list of the species recognized amongst Babu Bankim Behari Gupta's collection from the basal horizon in Sind is as follows :—

Dinotherium sindiense Lyd.
Tetrabelodon angustidens var. *palæindicus* Lyd.
Hyotherium sindiense Lyd.
Listriodon n. sp.

Hyoboops palæindicus Lyd.
Hemimeryx blanfordi Lyd.
Microbunodon cf. *silistrensis* Pent.
Dorcabune sindiense Pilg.
Propalæomeryx exigua Pilg.

At a horizon some 500 to 600 feet higher, which is correlated with the Chinji zone, occur the following:—

Tetrabelodon macrognathus Pilg.
Hyotherium chinjiense n. sp.
Listriodon pentapotamiæ Lyd.
Hemimeryx pusillus Lyd. sp.
Dorcabune anthracotheroides Pilg.
Dorcatherium minus Lyd.
Giraffokeryx chinjiensis Pilg.

500 or 600 feet higher occur the following Dhok Pathan species:

Hipparion punjabiensis Lyd.
Rhinoceros sevalensis Lyd.
Antelopine n. gen. Pilg. sp. *latidens* Lyd.

Amongst Mr. Pinfold's fossils from the Kamlial beds I have recognised *Hyotherium sindiense*, the species of *Listriodon* intermediate in character between *Listriodon Lockharti* and *Listriodon pentapotamiæ*, also *Hyoboops palæindicus* and a species of *Chalicotherium* distinct from that found in the Chinji beds.

In the beds above the Kamlial zone, considered by Mr. Pinfold to be of Chinji age, I have recognized the species *Hemimeryx pusillus*, which is a typical fossil of that zone.

In conclusion the new finds entirely support the idea that the Kamlial zone is much older than that of Chinji and is at least as old as the horizon of La Grive Saint Alban in Europe, if not that of Sansans.

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ON THE CRYSTALLOGRAPHY AND NOMENCLATURE OF HOLLANDITE. BY L. LEIGH FERMOR, D.Sc, A.R.S.M., F.G.S., *Superintendent, Geological Survey of India.* (With Plate I.)

IN my account of the manganese-ore deposits of India published in 1909,[1] I gave as full an account as was then possible of the mineral hollandite, first described in 1906[2]: and in a paper published in 1908,[3] and also in the above memoir, I discussed the relationship of hollandite to psilomelane and coronadite. These three minerals are considered to be manganates corresponding to the hypothetical acid H_4MnO_5, and it may be regarded as firmly established that hollandite and psilomelane are respectively the crystalline and amorphous or colloidal forms of the same chemical substance. In fact psilomelane is κ-hollandite, to use the suggestion of E. T. Wherry.[4] Since the foregoing accounts were published I have discovered that Prof. A. Lacroix has applied the term *romanéchite* to a crystalline mineral, from Romanèche in France, that appears to be identical with, or closely allied to, hollandite.

In the accounts referred to above the crystallography of hollandite is left in an unsatisfactory condition. But when on study leave in Cambridge in 1914, I was able to study several additional crystals of this mineral from the Kajlidongri manganese mine, Jhabua State, Central India, the original locality, and I must take this opportunity to thank Prof. W. J. Lewis for the facilities accorded

[1] *Mem. Geol. Surv. Ind.*, XXXVII, pp. 87-97.
[2] *Trans. Min. Geol. Inst. Ind.*, I, p. 76.
[3] *Rec., G. S. I.*, XXXVI, pp. 295-300.
[4] See p. 120.

me for working in the Mineralogical Laboratory of the University and Dr. A. Hutchinson for very valuable help and advice during the course of this investigation, a preliminary account of which has already been given.[1]

The object of this paper is twofold: namely to give an account of the crystallographic characters of hollandite, and to clear up the confusion in its nomenclature due to the existence of the duplicate name romanéchite.

I. THE CRYSTALLOGRAPHY OF HOLLANDITE.

The material studied was derived almost entirely from the Kajlidongri mine: a portion was collected by me at the time of my visit in 1905 (specimens J. 948, crystals 1 to 14), and the remainder was collected in subsequent years by the manager of the mine, Mr. H. J. Winch, who presented the Geological Museum with a fine series of crystals (specimens K. 302, crystals 15 to 20).

The material collected by me was found as scattered crystals in thin quartz veins traversing the manganese ore-body. These crystals vary greatly in size—from about $\frac{1}{8}$ inch to an inch in height—and are usually of stumpy habit, the dimension in the direction of the vertical axis being often less than those in the direction of the lateral axes. The crystals frequently exhibit terminal pyramid faces, which, however, are usually too dull to be of value for crystallographic purposes. As this was the only material available when I drew up the account published in 1909, I was baffled by the striation of the prism zone and the dullness of the pyramidal terminations, in my attempt to determine the crystal system of this mineral. In fact I was compelled to write (p. 90):—

'but the few angular measurements I have yet been able to make indicate that the mineral is either orthorhombic or triclinic, more probably the latter, and in either case very closely approaching the tetragonal form.'

The material forwarded by Mr. Winch included a large number of prisms of hollandite, which in general habit were longer than broad and ranged up to 2 inches in length. Mr. Winch states that "the large crystals ... were not found in the quartz veins as the small ones were found to occur, but were in small clusters on the outside of the ore-body protruding their crystals into rotted country-rock."

[1] *Rec., G. S. I.*, XLV, p. 98 (1915).

It was found necessary to wash soft talcose material off the crystals. Many of the crystals are pyramidally terminated at one end, some of the pyramidal faces being smooth and bright enough to yield fairly good images. As before, the prism zone is much striated, and the crystals are often fractured. Cracks parallel to the vertical axis have often produced a slight shifting or rotation of one part of the crystal relative to the remainder, whilst in some cases a crystal is probably built up of a parallel growth of prisms not always strictly parallel to each other. It was such defects as these that had previously prevented me from obtaining consistent readings in the prism zone. But by selecting the best crystals and painting out the cracked parts I have now been able to secure somewhat better results and to prove that hollandite belongs to the pyramidal group of the tetragonal system.

In general habit the crystals examined, which vary in length from $\frac{1}{8}$ inch to $1\frac{1}{2}$ inches, are tetragonal prisms of the first order (110), with the corners modified by the second order prism (100) and a series of hemihedrally developed ditetragonal prisms, of which the chief is (210). These prisms are terminated by a very flat pyramid taken as (111), modified in one case by the additional form (331).

I will now give a summary of the readings, of which four sets were recorded. The most numerous are those from faces in the prism zone. Measurements were also made of the angles (pp') between adjacent faces of the terminal pyramid, (pp'') between opposite faces of the pyramid, and (pm) between the pyramid and the unit prism.

The measurements of the pyramid faces may be considered first, as proving that the mineral belongs to the tetragonal system, and the prism measurements later as confirming the above deduction and assigning the mineral to the pyramidal (pyramidal-hemihedral or bipyramidal) group of this system.

The cause of the previous doubt concerning the system to which this mineral should be referred was an alternation in the values of the angles pp' to $p'''p$ as measured round the top of one crystal. This crystal (no. 1) gave the following measurements :—

$$\begin{aligned} pp' &= 22^\circ\ 2' \\ p'p'' &= 24^\circ\ 21' \\ p''p''' &= 20^\circ\ 53' \\ p'''p &= 24^\circ\ 11'' \end{aligned}$$

These measurements were, however, of great uncertainty, as they were derived from readings of the position of the shimmer from very dull and rough faces, often somewhat curved.

The values of the angle *pp′* obtained from this earlier batch of crystals ranged from 18° 26′ to 24° 21′ and must all be discarded. Omitting the two lowest values, which were by far the most unreliable, the eight remaining values give an average of 23° 8′.

The terminal faces of the crystals subsequently studied (nos. 15, 16, 17, 18*a* and 20) were of much better quality and yielded images of the signal. From these 5 crystals were obtained 16 measurements of *pp′*, etc., ranging between 22° 6′ and 24° 25′. The suggestion of orthorhombic symmetry conveyed by the alternation of values on crystal no. 1 quoted above is not supported by these crystals. Thus the readings from three of these crystals were as follows :—

Crystal.	*pp′*	*p′ p″*	*p″ p‴*	*p‴ p*
16	22° 20′	22° 36′	22° 51′	22° 9′
17	22° 6′	22° 47′	22° 38′	22° 49′
18*a*	24° 35′	21° 53′	22° 42′	23° 9′

Two values were very good and better than the remainder ; they were 22° 38′ on no. 17 and 22° 34′ on no. 20, the latter being the best of all. The mean of these two values, namely 22° 36′ has, however, been adopted for the calculation of the elements of the mineral. It is interesting to note that the mean of the 10 best values is also 22° 36′.

For the angles *pp″* and *p′ p‴* the following values were obtained :—

Crystal.	*pp″*	*p′ p‴*
16	31° 50′	31° 49′
17	31° 51′	32° 3′
18*a*	32° 18′	32° 10′
20	32° 7′	32° 27′

The mean of all these values is 32° 4′, whilst the mean of the four best values—31° 51′, 32° 3′, 32° 7′, and 32° 10′—is 32° 3′.

For the angles *pm*, *p′m′*, etc., 6 readings were obtained on crystals 15 and 16, ranging from 73° 45′ to 74° 6′, with a mean of 73° 57′, the best values being 73° 48′, and 74° 0′, measured on crystal 15 and averaging 73° 54′.

The foregoing measurements may be summarised as follows :—

Angle.	Number of readings.	Limits.	Mean.	Corresponding value of pp''.	Mean value of pp''.
pp'	10	22° 6′—22° 51′	22° 36′	32° 10′	32° 7′
pp''	8	31° 49′—32° 18′	32° 4′	32° 4′	
pm	6	73° 45′—74° 6′	73° 57′	32° 6′	
		Best values.			
pp'	2	22° 34′ and 38′	22° 36′	32° 10′	32° 8′
pp''	4	31° 51′—32° 10′	32° 3′	32° 3′	
pm	2	73° 48′ and 74° 0′	73° 54′	32° 12′	

There is thus a fair agreement between the values of pp'' deduced in three different ways. The values adopted are :—

$$pp' = 22° 36'.$$

and therefore $pp'' = 32° 10'$, and $cp = 16° 5'$,

and $\frac{1}{c} = 0{\cdot}2039$.[1]

In addition to the pyramid p (111), crystal no. 18 shows a face belonging to another pyramid q; this face is very poor and only shimmer reflections could be obtained. By taking the mean of 6 readings a value of 48° 54′ for mq was obtained. This gives the value of cq as 41° 6′. The calculated value of the angle 331 $\wedge$ 001 is 40° 52′. It is concluded, therefore, that q is the form (331). Other crystals show signs of the existence of this form.

It has already been noticed that a suggestion of alternation in the values of the angles between successive pairs of adjacent pyramid faces on the crystals first measured threw doubt on the tetragonal character of hollandite, the orthorhombic system being suggested. Similarly when measurements were made of the prism zone on the same material the values of the angle mm', etc., were seldom found to be 90° and there was a suggestion of an alternation of values in this case also. Even when the new material was studied one crystal (no. 16), measured all the way round, gave the following values for mm' etc. :— 90° 15′; 89° 14′; 90° 48′; 89° 43′, whilst no crystal has been found giving 4 values all approaching 90° within a few minutes. Furthermore these prisms usually have the edges truncated by narrow

[1] This value was erroneously given as 0·2283 in *Rec., G. S. I.*, XLV, p. 98.

faces in the approximate position of the prism of the second order $a(100)$. But very rarely has the angle *am* been found to be 45° or within a few minutes thereof. This is frequently due to the fact that instead of the face (100) the corner of the crystal is occupied by a series of faces of prisms of the third order making angles with *m* ranging from 41° to 52°, and building up a composite (100) face. But the form (100) itself is undoubtedly often present.

From the evidence derived from the prisms (110) and (100) as detailed above, it would be difficult to uphold the tetragonal character of hollandite, and it might, indeed, be maintained that the mineral is orthorhombic, with the axial ratio $a : b$ nearly $= 1 : 1$. But many of the crystals also exhibit very numerous faces of the general symbol (hko), which may be regarded either as tetragonal prisms of the third order or as ditetragonal prisms only hemihedrally developed. Any one of these forms when fully developed—*e.g.*, (210)—shows only 4 faces, and the distribution of these faces as indicated in the stereogram (Plate 1, fig. 2) prevents us from regarding the mineral as orthorhombic.

Also the four faces assigned to each of the forms (hko), (110), and (100), cannot be regarded as two pairs of triclinic pinacoids on a triclinic mineral with axial ratios and angles approximating to tetragonal values, because the measurements of the angles *mp* give no indications outside the limits of probable experimental error that the vertical axis $\dot{c}$ of the mineral is not at right angles to the plane of the lateral axes. Thus on crystal 16 the following four values of *mp*, etc., were obtained :—

$$mp = 74^\circ\ 6'$$
$$m'p' = 74^\circ\ 0'$$
$$m''p'' = 74^\circ\ 2'$$
$$m'''p''' = 73^\circ\ 45'$$

In view of all the foregoing facts we are compelled to conclude that hollandite is tetragonal, and further, on the evidence of the forms (hko), that it must be referred to the pyramidal or scheelite class. The departures of the values of *mm'* from 90° and of *ma* from 45° must, therefore, be due to imperfections in the crystals, such as those already referred to.

I have already mentioned that the crystals often exhibit a great number of hemihedrally developed ditetragonal prisms or prisms of the third order of the general form (hko). In determining these forms by measurements with reference to the form $m(110)$ care has to be taken to eliminate wherever possible the effects of the dis-

placement by cracks or rotation of the various faces of the form *m*. The commonest form of the general symbol (hko) is one marked *k* in Plate 1, fig. 1, making the angle 18° 26′ with one adjacent face of *m* and 71° 34′ with the other. The value 18° 26′ for *mk* corresponds to the form (210) and the complement to the form (120). I have assumed this form to be (210) and the reading of the crystals is based on this assumption. If it be desired to regard this form as (120) all that is necessary is to invert the crystal as drawn in Plate 1, fig. 1, when the face *k* will be found to lie to the left of *a* instead of to the right, and the index of this face becomes $\bar{2}10$ instead of 210. From this it is seen that right-handed hollandite can be converted into left-handed hollandite by inverting the crystal. The readings of the faces of the forms (hko) lying between each pair of prism faces have all been referred to the particular face of *m* lying nearest to *k*. Since *mm′* in practice often varies considerably from 90° it follows that if the readings were referred to the more distant face of the form *m*, the values of *m′k* thus obtained would differ somewhat from the value of $\frac{\pi}{2} - mk$. The method of averaging as many readings as possible must, however, reduce this error to a minimum. Moreover, the values of the angle $110 \wedge hko$ for faces lying fairly near to 110 are much less likely to be erroneous than those more remote, especially than those more than 45° away from 110. As will be seen from the tabular statement of readings in the prism zone, 42 out of 57 forms with the general symbol (hko) lie between 110 and 100 and only 15 between 100 and 110.

The large number of forms present on many crystals, and the fact that there is often an alternation of two forms several times repeated, frequently gives rise to a close striation of portions of the prism zone. This striation often acts as a diffraction grating and produces spectral series of images in the telescope of the goniometer. Whenever a doubt arose as to which images should be accepted as due to reflections from faces and which should be rejected as due to diffraction, the lens in front of the objective was lowered into position to see whether or not there was a face corresponding to the image in question. All the readings to which any value could be attached have been collected in the following table, from which it will be seen that the presence of many of the forms listed has been deduced from only one or two readings; but even in these cases the readings were found to correspond to a narrow face in almost every

case. The doubt is not whether this large number of forms exists, but whether the correct symbols have in every case been assigned to them. In some cases the symbol assigned is doubtless incorrect owing to a faulty reading, whilst in others, in which the reading was probably close to the true value, the difficulty has been to decide to which of two or more closely related forms the reading in question should be referred. Since we seem bound to accept as present certain forms with high indices in their symbols, *e.g.* (50. 49. 0) and

TABLE OF ANGLES OF FACES IN PRISM ZONE WITH *m* (110).

Number of readings.	Range.	Mean.	Calculated value.	Symbol of form.	Remarks on images, etc.
3	0° 34′— 0° 36′	0° 35′	0° 35′	50. 49. 0	Fairly good (edge), distinct, fair (edge).
2	1° 38′— 1° 50′	1° 44′	1° 44′	17. 16. 0	Faint, faint, distinct.
4	2° 9′— 2° 23′	2° 14′	2° 16′	13. 12. 0	Thin edges, good image (edge).
4	3° 7′— 3° 43′	3° 23′	3° 22′	980	Fair (edge), faint.
1	4° 10′	4° 10′	4° 24′	760	Faint.
4	5° 47′— 5° 54′	5° 49′	5° 42′	11. 9. 0	Blurred, faint.
1	7° 30′	7° 30′	7° 26′	13. 10. 0	Brightish.
1	7° 58′	7° 58′	8° 8′	430	Do.
6	9° 13′— 9° 36′	9° 23′	9° 28′	750	Faint, very good, very faint.
2	10° 56′—11° 13′	11° 5′	11° 19′	320	Very faint.
2	11° 33′—11° 54′	11° 44′	11° 58′	20. 13. 0	Fairly good, very faint.
1	13° 33′	13° 33′	13° 24′	13. 8. 0	Faint.
1	14° 11′	14° 11′	14° 2′	530	
2	15° 22′—15° 45′	15° 33′	15° 38′	16. 9. 0	Edge.
1	16° 10′	16° 10′	16° 11′	20. 11. 0	Fair (edge).
8	17° 3′—17° 32′	17° 17′	17° 18′	40. 21. 0	Bright, fair (edge), faint, thin edge
1	17° 58′	17° 58′	17° 59′	100. 51. 0	Edge.
12	18° 12′—18° 56′	18° 30′	18° 26′	210	Good (face), good (edges), faint.
6	19° 9′—19° 33′	19° 24′	19° 21′	25. 12. 0	Good (edge), very faint.
3	21° 33′—21° 59′	21° 48′	21° 48′	730	Good, fair (edge).
3	22° 24′—22° 42′	22° 33′	22° 33′	12. 5. 0	Fairly good (edge).
2	3° 9′—23° 32′	23° 20′	23° 12′	520	Fairly good, faint distinct.
2	4° 5′—24° 26′	24° 15′	24° 27′	830	Fairly good (edge), faint distinct.
1	26° 40′	26° 40′	26° 34′	310	Fair (edge).
2	19′—27° 48′	27° 34′	27° 54′	13. 4. 0	Fairly good (edge), fair (edge).
3	28° 7′—28° 10′	28° 9′	28° 18′	10. 3. 0.	Bright (face), fair (edge), faint.

Number of readings.	Range.	Mean.	Calculated value.	Symbol of form.	Remarks on images, etc.
1	28° 34′	28° 34′	28° 37′	17. 5. 0	Distinct.
1	28° 55′	28° 55′	29° 3′	720	Do.
2	30° 48′—31° 12′	31° 0′	31° 0′	410	Fair, faint (edge).
2	31° 55′—31° 58′	31° 57′	32° 0′	13. 3. 0	Bright (edge), distinct.
1	32° 23′	32° 23′	32° 28′	920	Blurred.
2	33° 40′—33° 41′	33° 41′	33° 41′	510	Brightish, faint.
1	38° 5′	38° 5′	38° 9′	25. 3. 0	Thin edge.
1	39° 9′	39° 9′	39° 16′	10. 1. 0	Good (thin edge).
4	39° 38′—40° 5′	39° 52′	39° 48′	11. 1. 0	Bright (facet), faint, blurred.
1	40° 25′	40° 25′	40° 14′	12. 1. 0	Bright (facet).
3	40° 55′—41° 27′	41° 10′	41° 11′	15. 1. 0	Good (edge) } These forms tend to build up one composite face. } 100 with vicinal faces.
2	41° 31′—41° 55′	41° 43′	41° 43′	17. 1. 0	Good
2	42° 30′—42° 58′	42° 44′	42° 44′	25. 1. 0	Good (thin edge).
2	43° 10′—43° 18′	43° 14′	43° 12′	32. 1. 0	
3	43° 49′—43° 59′	43° 54′	43° 54′	52. 1. 0	Thin edge
27	44° 8′—45° 34′	44° 56′	45° 0′	100	Fairly good, fair (thin edge).
2	46° 10′—46° 33′	46° 21′	46° 22′	1. 42. 0	Very thin edge.
2	46° 57′—47° 21′	47° 9′	47° 7′	1. 27. 0	
2	48° 35′—48° 42′	48° 38′	48° 35′	1. 16. 0	Fairly bright, distinct.
2	49° 6′—49° 24′	49° 15′	49° 5′	1. 14. 0	Well defined face.
2	50° 11′—50° 17′	50° 14′	50° 12′	1. 11. 0	Bright.
2	51° 15′—51° 15′	51° 15′	51° 20′	190	Faint.
1	52° 41′	52° 41′	52° 36′	2. 15. 0	
1	53° 23′	53° 23′	53° 8′	170	Brightish.
1	54° 23′	54° 23′	54° 28′	160	Faint.
1	55° 36′	55° 36	55° 18′	2. 11. 0	Distinct.
1	58° 23′	58° 23′	58° 15′	4. 17. 0	Very thin edge.
2	68° 35′—68° 42′	68° 39′	68° 38′	7. 16. 0	Distinct face, thin edge.
1	70° 15′	70° 15′	70° 30′	12. 25. 0	Very thin edge.
1	74° 52′	74° 52′	74° 45′	470	Approximate.
1	88° 34′	88° 34′	88° 32′	19. 20. 0	Faint.

(52. 1. 0), it is obvious that we may not, in a doubtful case, be correct in selecting from two possible forms that with the simpler indices, although this course has been followed.

The tabular satement shows no less than 57 forms of the general symbol (hko).

Although, as explained, considerable doubt attaches to many of the forms given in the table, some must be accepted as almost certainly present, namely the following :—

(50. 49. 0), (13. 12. 0), (980), (11. 9. 0), (750), (41. 20. 0), (210), (25. 12. 0), (730), (12. 5. 0), (11. 1. 0), (15. 1. 0), (17. 1. 0), (52. 1. 0), and the prism of the second order (100).

All the above forms lie between *m* and *a*, but in addition there are a number of forms between *a* and *m‴* (or between *m* and *a′*), but as none of these are represented by more than 2 readings none of them can be accepted with certainty. Perhaps (1. 16. 0), (1. 11. 0), (190), and (7. 16. 0) may be accepted on account of the closeness of the two readings. Only one of the fifteen forms between *a* and *m‴* corresponds to a form between *m* and *a*; this is (1. 11. 0), the hemihedral form of (11. 1. 0).

In Plate 1, fig. 1, is represented a crystal of hollandite in clinographic projection showing the forms *p* (111), *m* (110), *a* (100), and *k* (210), the last-named being the commonest of the third-order prisms found in hollandite. Fig. 2 shows a stereographic projection of the same crystal with a few additional faces, including the pyramid *q* (331), the prisms of the third order (41. 20. 0), (750), (980), and the twin plane $\bar{1}.\,\overline{10}.\,\bar{1}$ referred to on page 115.

Several crystals as simple as that depicted exist amongst those first studied, but amongst the second batch of crystals a large number of additional prisms of the type (hko) are often present on one crystal. Thus crystal no. 16 gave readings corresponding to no less than 38 of the third-order prisms enumerated.

An idea of the association of various forms in the prism zone can be obtained from the accompanying figure (no. 1) of a portion of crystal 15 enlarged. The repetition of the forms (210) and (110) may be noted. Similarly figure 2 shows diagrammatically a portion of

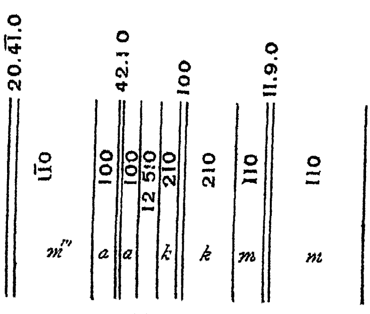

FIG. 1.

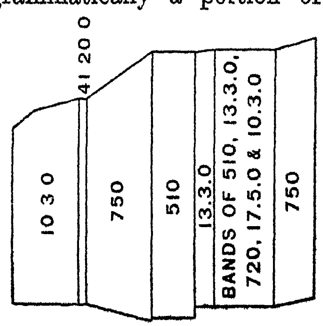

FIG. 2.

crystal 20. It will be noted that one broad face is really composite and is built up of no less than 5 forms, if any use can be made of the poor images obtained.

In addition to the material from Kajlidongri two other specimens (L. 229) with crystalline hollandite were available for study. These were received some years ago from Mr. H. J. Winch, who collected them at Banswara in Rajputana. The principal specimen was originally a tabular slab some 7 inches long and $1\frac{1}{2}$ to $2\frac{1}{2}$ inches wide, from which two smaller pieces have since become detached. This slab is from $\frac{1}{4}$ to $1\frac{1}{4}$ inches thick and is composed of an exceedingly fine-grained manganese-ore, probably hollandite; one surface of the slab is studded with a large number of irregularly disposed prismatic crystals ranging from a minute fraction of an inch to over an inch in length, which is on the average 3 to 5 times the diameter.

These crystals are apparently square prisms with the corners bevelled by the second-order prism (100), sometimes associated with third-order prisms of the general form (hko). Finally, when terminated, these crystals show crudely developed faces of a flat pyramid, apparently the same as that of hollandite. In fact general inspection of the crystals leaves little doubt that the mineral is hollandite.

The particular interest of this specimen depends upon the fact that amongst the crystals is a butterfly twin. This could not be measured without detaching it and spoiling the specimen, but fortunately the second specimen, which is also tabular but much smaller—about 1 inch square,—carried a second twin crystal, which had brighter faces than the twin on the large slab. From this second specimen I detached a piece, showing the twin crystal and several associated prisms, and small enough for examination on the goniometer.

As the crystals on these two specimens have not been subjected to chemical analysis, except for a few qualitative tests, the proof that they are hollandite must depend on the crystallographic measurements. Unfortunately the faces are mostly rather dull and likely to give only approximate readings, but the crystals on the smaller specimen are brighter than the average. I will first show that the angular measurements, though rough, prove that the mineral is hollandite, and then consider the twinning.

One chip giving fair reflections yielded the following values :—

$$mm' = 89^\circ\ 53'$$
$$ma' = 44^\circ\ 50'$$
$$m'a' = 45^\circ\ 3'$$

and also showed a face corresponding to a prism of the form (hko) making an angle of 15° 42′ with *m*.

Other crystals yielding worse images gave values for *mm′* and *ma′* usually much more remote from 90° and 45° respectively than the above, namely :—

$$mm' = 88° 58', 89° 51', 90° 33', 91° 21'.$$
$$ma' = 44° 41', 45', \text{and } 45° 17', 26', 48', 48', 53'.$$

In another prism *a* was missing and the form *m* was combined with one of the forms (hko), the following values of $m \wedge$ hko being measured :—18° 16′ and 20°, the reading for hko in the latter case being obtained by shimmer and therefore only approximate. These two readings evidently indicate the presence of the form (210), which is present only hemihedrally developed. The value 15° 42′ for $m \wedge$ hko obtained on the crystal first mentioned probably indicates the presence of the form (16. 9. 0), the theoretical value for the angle $m \wedge$ hko being then 15° 38′.

Accepting the values obtained from the best crystal it is evident that the mineral is tetragonal, whilst the hemihedral development of the form (210) indicates that the mineral must be referred to the pyramidal group of the system. The terminal pyramid present on some of the crystals looks exactly like that on the crystals from Kajlidongri, although too dull for measurement. We are, therefore, compelled in view of all the above to accept the Banswara mineral as hollandite.

We can now consider the twin crystals. The one measured is indicated diagrammatically in fig. 3. On attempting to measure the

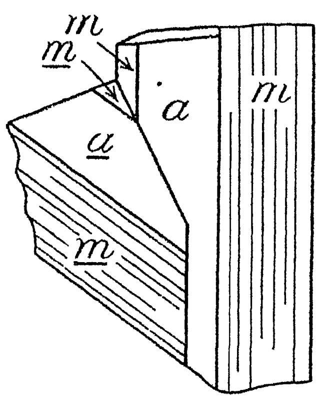

FIG. 3.

value of the re-entrant angle $a \wedge \underline{a}$, several images were obtained indicating possible values from 10° 54′ to 13° 12′, of which the best value was evidently 10° 54′.

Measurements were also made of the angle on the face $\underline{a}$ between the trace of the twin plane and the edge $\underline{a}\underline{m}$. These measurements were carried out on the stage of an ordinary petrological microscope by means of the cross wires. A mean value of 27° 26′ was obtained.

From these measurements I have calculated that the plane of twinning belongs to the form (1. 10. 1), the actual face present with the orientation of the crystal adopted being $\bar{1}. \bar{10}. \bar{1}$.

The value 10° 54′ gives $90° - \frac{10° 54'}{2} = 84° 33'$ as the value of the angle hkl $\wedge$ 100. The calculated value of 1. 10. 1 $\wedge$ 100 is 84° 17′.

Similarly the angle between the zone (100) (110) or [001] and the zone (100) (1. 10. 1) or [0. $\bar{1}$. 10] is by calculation 27° 37′, as compared with 27° 26′, the value experimentally obtained.

We have seen above that hollandite belongs to the pyramidal group of the tetragonal system, of which the type mineral is scheelite. The value for *pp″* accepted for hollandite is 32° 10′, giving the value of $\dot{c}$ as 0·2039, whereas the value for *pp″* in scheelite is 130° 33′ giving a value of 1·5356 for $\dot{c}$. These figures reveal no apparent relationship between the two minerals. But if, noticing that the angle *dd″* in scheelite is 34° 9′, we alter the orientation of our hollandite crystals, so that the form *p* (111) becomes *d*(105), the value of $\dot{c}$ then becomes 1·4116 as compared with the value 1·5356 in scheelite (and with 1·4643 in fergusonite).

In the memoir and other papers already referred to it is concluded that both psilomelane and hollandite are manganates corresponding to the hypothetical acid $H_4 MnO_5$; it is also shown that the analyses of the psilomelanes and romanéchite from Romanèche given by M. Gorgeu agree better with this assumption than with the view held by both Gorgeu (and Lacroix) that these two minerals are manganites,[1] and further that the analyses of the coronadite of Arizona given by Lindgren and Hillebrand can be interpreted as indicating a manganate, instead of a salt of the manganous acid $H_{10} Mn_{12} O_{29}$, as deduced by the authors cited.[2] In case the differences between the amounts of oxygen required in the analyses of all the above minerals

[1] *Mem., G. S. I.*, XXXVII, pp. 96 and 105.
[2] *Rec., G. S. I.*, XXXVI, p. 296.

for their interpretation as manganates or as manganites respectively should be regarded as lying within the limits of experimental error for careful determinations of the amounts of available oxygen, so that the closer agreement of the analyses with a manganate formula than with a manganite formula could not be regarded as decisive in determining this point, it is legitimate to summon to our aid the indirect evidence provided by the fact that hollandite belongs to the scheelite group of crystals. The formula of scheelite may be written $CaO.WO_3$, and that of hollandite in its simplest form $2RO.MnO_3$, the crystallographic relationship of the two minerals being then correlatable with a chemical relationship, dependent presumably on a similarity in structure between the two radicles WO_3 and MnO_3. An attempt to interpret hollandite as a manganite allows of no satisfactory chemical comparison of the two minerals.

Pursuing this train of thought further it is interesting to notice that the total number of minerals belonging to the scheelite group of crystals as recorded in Dana's 'System of Mineralogy' and its three Appendices is only eight, namely:—wernerite, sarcolite, fergusonite, scheelite, cuprotungstite, powellite, stolzite, and wulfenite. The two first minerals are silicates; fergusonite is a tantalo-niobate of the formula (Y, Er, Ce) (Nb, Ta) O_4; and the remaining five minerals form the very compact scheelite group of minerals—tungstates and molybdates with the general formula $R(W,Mo)O_4$. In a systematic work on mineralogy the manganates should obviously be placed in the scheelite group, or in a new group immediately adjoining.

II. THE NOMENCLATURE OF HOLLANDITE.

This must be considered from two points of view:—

(1) that there is an alternative name in the field.

(2) that hollandite is the crystalline form of a long-known amorphous mineral—psilomelane.

The term *romanéchite* was introduced by Prof. Lacroix as long ago as 1900 in the 'Guide du Visiteur' to the 'Collection de Minéralogie du Muséum d'Histoire Naturelle,' in which, on p. 29, under the heading 'Manganites' appears the entry

'Romanéchite. . . . . Mn_3O_7 (Mn,Ba). H_2O ?'

the ? referring to the crystalline system. No description of this mineral was, however, offered until 1910, when Prof. Lacroix on pp. 6 to 12 of Vol. IV of his 'Minéralogie de la France et de ses Colonies' gave

an account of the physical and chemical characters and mode of occurrence of this mineral, referring it to the psilomelane group and continuing to regard it as a manganite, the formula $H_2(Mn,Ba)Mn_3O_8$ being assigned.

The name *hollandite* was first proposed in 1906, as related on page 103, and even in 1909 at the time of publication of the memoir there referred to, I had no knowledge of the existence of the name romanéchite. But in a footnote on p. 96 of that memoir I refer to some analyses of psilomelane (with a crystalline form) from Romanèche, published by Gorgeu in 1890, pointing out that these analyses which had been interpreted by Gorgeu as indicating manganites with 'bases multiples et variées,' can be better interpreted as indicating manganates, and also expressing the opinion that the crystalline part of the specimens is probably identical with hollandite.

Subsequent to this I discovered the existence of the name romanéchite and on proceeding on leave in 1910 broke the journey at Paris, and called upon Prof. Lacroix, who very kindly showed me his specimens of romanéchite. There could be little doubt after this that hollandite and romanéchite are either identical or closely allied.

As will be noticed later, there are certain differences in chemical composition between the romanéchite and the particular hollandites that have hitherto been analysed. Hollandite has, however, such a variable composition that I regard the particular composition of romanéchite as representing merely another variation of the hollandite formula.

Assuming it be agreed that only one specific name be necessary for the whole of these crystalline representatives of psilomelane the question arises as to which of these two names should be adopted.

In the principles of nomenclature given in the Introduction to Dana's 'System of Mineralogy,' 6th Edition, p. xliii, it is stated (para. 13, *c*) that a name having priority may properly be set aside 'when it is put forward without a description.' The name hollandite has been so widely adopted and specimens of the mineral so widely distributed that it would be very difficult to displace it by the term romanéchite. It seems, therefore, desirable, to take advantage of the foregoing principle and to adopt the term hollandite in preference to romanéchite, at least as the comprehensive name for all these closely related manganates. This course is all the more justifiable and desirable because the term hollandite has already been given a

comprehensive meaning, whilst the term romanéchite has only been applied to the mineral from Romanèche.

Prof. Lacroix in his account of romanéchite published in 1910 [1] refers in a footnote to hollandite, pointing out that hollandite approaches romanéchite 'sans pouvoir toutefois être identifié avec elle, à cause de sa richesse en fer et du replacement total de l'hydrogène par les métaux.' A comparison of the analyses of romanéchite published by Lacroix and of those of hollandite published by me supports the foregoing remark (except that some hollandites contain water), as may be seen from the following statement of the composition of these two minerals :—

—	ROMANÉCHITE (7 ANALYSES).		HOLLANDITE (4 ANALYSES).	
	Range.	Mean.	Range.	Mean.
MnO_2 . .	64·97—69·69	66·96	65·63—75·05	71·09
MnO . .	7·28—14·77	10·10	5·12—14·20	9·36
Fe_2O_3 .	*nil* — 1·80	0·62	4·43—10·56	7·49
BaO . .	13·50—19·57	16·10	2·96—17·59	8·33
K_2O . .	*nil* — 0·37	..	*nil* — 3·31	0·83
H_2O . .	4·08— 5·00	4·53	*nil* — 1·10	0·40

It will be seen that the hollandites all carry more iron and less water than the romanéchites, but I do not think this can be regarded as indicating more than a varietal difference. The four hollandites came from four different localities and, it will be seen, show a considerable range of composition, whereas the 7 specimens of romanéchite, being all from Romanèche, naturally show a much smaller range of composition. It is indeed possible that analysis of a wider range of hollandites would reveal the existence of examples with much smaller amounts of Fe_2O_3. In view of the above analyses we may, however, adopt the name romanéchite as an alternative name for those varieties of hollandite that are high in H_2O and low in Fe_2O_3.

[1] *L. c*., p. 7.

It is desirable to keep the significance of the term hollandite as broad as possible, for it should be remembered that hollandite is to be regarded as the crystalline form of the amorphous mineral psilomelane. The five analyses of Indian psilomelanes given on p. 100 of *Mem., G. S. I.*, XXXVII, show the following range of composition :—

MnO_2	70·78— 83·13
MnO	3·61— 7·63
Fe_2O_3	0·07— 5·71
BaO	0·03 —15·08
K_2O	0·20— 3·10
H_2O	2 60— 3·80

whilst 11 other analyses on page 114 (excluding M. 4) show :—

MnO_2	73·14—84·12
MnO	*nil* —14·93
Fe_2O_3	*nil* — 9·51
BaO	*nil* —13·22
K_2O	*nil* — 4·26
H_2O	1·56— 8·97

These analyses also show small quantities of CaO (*nil*—4·49 per cent.), MgO(*nil*—4·31 per cent.), Na_2O (*nil*—0·43), Al_2O_3 (0·10—2·98), CoO and NiO (*nil*—1·52), CuO (*nil*—0·12) and ZnO (*nil*—0·30). Small quantities of all these constituents are also shown in the five analyses referred to.

The 11 analyses summarised above were obtained by calculation from analyses of specimens of manganese-ores composed of mixtures of braunite and psilomelane, in which the braunite formula was satisfied first, the remaining constituents being then taken into the psilomelane. Thus the presence or absence of Fe_2O_3 in the above analyses depends largely upon whether the iron in the original analysis has been calculated into the braunite or the psilomelane, in whole or in part.

Judging from the wide range of composition indicated by the foregoing analyses it seems probable that for every variety of crystalline manganate (hollandite or romanéchite) there is an amorphous form (psilomelane) and that all the manganates form an isomorphus series. As has already been pointed out, a third manganate (regarded as a manganite by its discoverers) is known, namely coronadite, in which lead plays an important part, whilst Ba, Fe, and H are absent or low. Assuming that crystals of coronadite when found will prove to be isomorphous with hollandite, then coronadite should also be included in the hollandite group.

The views given above may be summarised as follows :—

$$\text{Hollandite Group}\left\{\begin{array}{l}\left.\begin{array}{l}\text{Pb low or absent}\\ \text{Ba low to high}\end{array}\right\}\text{Hollandite}\left\{\begin{array}{l}\left.\begin{array}{l}\text{High in } H_2O\\ \text{Low in } Fe_2O_3\end{array}\right\}\text{Romanéchite}\\ \left.\begin{array}{l}\text{Low in } H_2O\\ \text{High in } Fe_2O_3\end{array}\right\}\text{Hollandite, } \textit{sensu str.}\end{array}\right.\\ \left.\begin{array}{l}\text{Pb high}\\ \text{Ba absent or low}\end{array}\right\}\text{Coronadite}\end{array}\right.$$

We may now consider the fact that hollandite must be regarded as the crystalline form of psilomelane. A question of general principle at once arises. Should the crystalline and amorphous or colloidal forms of the same chemical substance receive the same or different names? A correct answer to this question may be of some importance as the study of the amorphous forms of minerals extends. Dr. E. T. Wherry has suggested that the colloidal form should be distinguished from the crystalline form by prefixing the Greek letter κ to the name of the latter [1]; according to this suggestion psilomelane would be called κ-hollandite.[2]

It so happens, however, that the colloidal mineral, psilomelane, was discovered and named before the crystalline mineral, hollandite, and has such a well-known name that it could not be displaced by such a name as κ-hollandite. It is obvious, therefore, that we also require a letter for prefixing to the name of the amorphous form, when this, as in the present case, has been discovered first, and I suggest that a capital X be employed for this purpose. Thus an alternative name for hollandite would be X-psilomelane. In the case of minerals of complex and variable composition a wide range of compositions may shelter under one name as long as the substance remains amorphous: but in the crystalline phase the variations in composition may produce sufficiently marked difference to necessitate separate names for different sections of an isomorphous series. Thus if measurable crystals of romanéchite be ever found they may yield a value for pp' sufficiently different from that of the ferro-hollandite of Kajlidongri to justify the maintenance of separate names.

Nevertheless the possibility of prefixing the letter X to the names of amorphous minerals to denote the crystalline phase of the same and of prefixing the letter κ to the names of crystalline minerals to denote the colloidal phase may be very useful in many cases and often render unnecessary the invention of new names.

[1] *Centralblatt f. Min. Geol. u. Pal.*, 1913, p. 518.
[2] Not κ-manganite as shown by Wherry.

GEOLOGY AND ORE DEPOSITS OF THE BAWDWIN MINES BY J. COGGIN BROWN, M.SC., M.INST.M.M., M.I.M.E., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 2 to 8.)

CONTENTS

PART I.

INTRODUCTION.

THE Bawdwin Mines of the Burma Corporation Limited lie in Longitude 97° 18′, Latitude 23° 6′, approximately, in the Tawnpeng (Taungbaing) State, one of the smaller Northern Shan States. They are connected with the Mandalay-Lashio section of the Burma Railways by a narrow-gauge (two-foot) line, 50 miles long, that meets the Burma Railways at Namyao, 517½ miles from Rangoon and 167½ miles from Mandalay. The narrow gauge railway, which winds about in the usual manner of mountain lines, crosses the Namtu river at Nam Tu, the site of the head offices, smelters and residential quarters of the Company and then ascends through the gorge of the Nam Pangyun stream to Bawdwin, gaining elevation as it does so by means of a spiral loop and double reverse. The first section of the line passes through typical Shan States scenery, light jungle growth being prevalent everywhere; but having gained the Pangyun gorge the country changes, the hills becoming higher and more precipitous and the vegetation gradually disappearing, until in the vicinity of Bawdwin itself, nothing but dense grass clothes the slopes. The absence of forest in this country is very remarkable and gives the locality a peculiar aspect as seen from surrounding heights. It is due partly to the destruction of trees by the ancient miners in their search for fuel, and partly to the blighting action of the gases from their smelting operations.

According to Maclaren the average height of the mine area above sea level is 3,200 feet. The collar of the vertical shaft is about 3,240 feet. The lowest part of the concession below the mouth of the E. R. valley is 2,790 feet, while the highest (Mount Herschell) is 4,615 feet. The bed of the Nam Pangyun drops 1,000 feet while passing through the lease. The average depth of the bed of the river beneath the crests of the ridges on either side is 1,000 feet. The area of the concession is 2,496 acres and all the known old workings and slag heaps lie within it.

Previous work and acknowledgments.

Geological field work was commenced in the immediate vicinity of Bawdwin by Dr. J. Malcolm Maclaren, then Mining Specialist

to the Government of India, in 1906. A preliminary report on the results of a fortnight's visit to the mines in February 1907 has been published by T. H. D. La Touche and myself (*Rec., Geol. Surv. Ind.*, Vol. XXXVII, Pt. 3, pp. 235-263). At that time it was found impossible to survey the area accurately until the completion of the 1 inch=1 mile map of the Survey of India. This was available in 1909-10 and the present investigation was undertaken in 1914-15 when I was again deputed to Bawdwin by the Government of India. The months of November, December and January were occupied by a study of the silver-lead-zinc ores discovered *in situ* since my earlier visit and by the mapping of the rhyolites and associated tuffs. In February, March and April I made extensive tours through the surrounding districts.

The reader should remember that while no effort has been spared to give as complete an account as possible it is certain that inaccuracies exist, owing to the fact that, with the exception of the region immediately adjacent to the mines, the whole country is covered with thick forests which make geological work a matter of considerable difficulty. Further, the Bawdwin mines, although operated for centuries by the Chinese, are still in the early stages of development and hardly a day passes without the revelation of some fact requiring a modification of a previously formed theory. With these reservations it may be stated that this report is intended to describe the broad outlines of the geology of the district and to summarize the available evidence regarding the origin and distribution of the ores.

I owe a great deal to the courteous co-operation of the Burma Corporation Limited who have invariably given free access to maps and plans and furnished any information asked for. Amongst those to whom I am particularly indebted are Mr. C. H. Macnutt, Resident Manager, Mr. T. E. Mitchell, Mines Manager, and Mr. M. H. Loveman, Geologist of the Company. The friendly help of these gentlemen given ungrudgingly in the office, the field and the mine, is gratefully acknowledged.

Only the geologist who has worked in unexplored parts of the Shan States is in a position to appreciate adequately the pioneer work of T. H. D. La Touche. It is entirely a result of his labours that new districts can be surveyed in any reasonable time at all. I have made free use of Dr. J. M. Maclaren's results as set forth in his earlier manuscript report to the Government of India, and his

later one written as a result of a recent visit on behalf of the Company. To both these gentlemen my thanks are here acknowledged.[1]

History of the Mines.

The Bawdwin Mines, known to the Burmese as "Bawdwingyi" or "Great Silver Mines," and to the Chinese as "Lao-Yin-Chang" or "Old Silver Mines," have been worked for silver for hundreds of years, though they did not attract the attention of Europeans before 1795.

The date of commencement of the Chinese operations at Bawdwin is lost in antiquity. It has been stated that this date was probably more than 1,000 years ago but there seems to be no authority for considering it as early as this (*Mining Journal*, Vol. LXXIX, p. 52). It is very doubtful if the mines were operated during the period when the Shan power was dominant over the country between the 5th and 13th centuries. Maclaren is of the opinion that Bawdwin was made Chinese during the invasion of 1343 A. D. and places considerable reliance on an inscription that came into his hands and which was said to have been found at Bawdwin. According to Mr. Taw Sein Ko, the Government Archæologist in Burma, this record states that work was commenced at Bawdwin by the Chinese in the 9th year of the Emperor Ch'ing-tsou (Yonglo) of the Ming dynasty. This date in western reckoning is 1412 A. D.

Recent Chinese records show that the mines were worked during the reigns of Chia Ching (1796-1821) and Tao Kuang (1821-1851). In the accounts of the early missions to the Burmese court at Ava, from that of Michael Symes in 1795, to that of Sir A. Phayre, who was accompanied by Dr. T. Oldham, Superintendent of the Geological Survey of India, in 1855, references can be found to the mines, but no European was allowed to visit them, and in 1895 when the 6th edition of the quarter-inch topographical map was compiled, so little was known of them that their position is not marked. Symes in 1795, calls the place Badouem, and says it is 6 days' journey from Bamoo (Bhamo) (Symes : Embassy to Ava, p. 324). Crawford in 1827, who had the advantage of seeing two

[1] While this report was passing through the press an account of the Bawdwin ore deposits has appeared by Mr. M. H. Loveman. It is interesting to note that this author, who has had unrivalled opportunities for studying the mine, has reached much the same conclusions regarding the origin of the ores as myself. See *Trans. Amer. Inst. Min. Eng.*, Bull. 120, Decr. 1916, p. 2119.

Chinese traders from Bawdwin, estimated the value of the annual production at 960,000 ticals or £120,000, while the royalty payable to the King of Ava was 4,800 ticals or £600 sterling per annum. He places the locality, which he calls Bor-twang, at 12 days' journey from Bhamo and states that the number of men employed was about 1,000 (Crawford: Journal of an Embassy to the Court of Ava, pp. 427, 444).

There are serious discrepancies between Crawford's statements and those of Dr. Oldham, who at the time of Sir A. Phayre's mission in 1855 says that 10,000 Chinese were employed at the mines, while the tax payable to the Burmese king was only 40 ticals or £5 per annum. This may indicate that the authority of the king over his frontier areas had waned and that the Chinese—ever ready to regard the surrounding tribes as barbarians while punctilious enough as regards official etiquette in their dealings with them—acknowledged the Burmese royal authority by a merely nominal fee. Oldham's statements that the mines at that time produced 60 viss (2,130 oz.) of silver per day and that the ore was reported to contain ½ per cent. silver (163 oz. per ton), though both probably are the natural exaggerations of his oriental informer, seem to prove conclusively that whatever may have been the real cause of the decrease in royalty, it was not due to the decline of the mining industry.

At the time of my first visit to Bawdwin there were abundant traces of the Chinese occupation quite apart from the furnaces and enormous slag dumps. A typical Chinese stone-paved road ran up the valley crossing the stream by three arched stone bridges in perfect preservation. In places the stream was kept in its course, and prevented from doing damage during the sudden floods to which it is liable, by retaining walls. Flat benches on the hill-side and valley bottom showed where the miners' dwellings had been situated. In one prominent position now occupied by the geologist's bungalow, were the remains of a large stone temple approached by a broad flight of stone steps and guarded by two carved stone lions. Thousands of graves cover the hillsides overlooking the valley, the majority merely mounds, others with tombstones bearing long inscriptions, the grave itself being occasionally marked out by boulders of quartz or barytes. The summits of the surrounding hills on the north, north-west and west are strongly fortified with deep trenches and high earthen banks. They have been estimated to stretch from 12 to 14 miles and are excellently disposed

both to resist attack and to prevent any escape from the mining area, a point which previous commentators have overlooked. The extensive deforestation of the surrounding country is also essentially Chinese. The bare appearance of the immediate neighbourhood and of the country to the north and north-east is most striking in a land clothed for the most part in primeval forest. It is due to several causes, the destruction of the timber for fuel supply of the smelters, the action of the acid fumes in the south-west monsoon, and, finally, to the general Chinese strategy which invariably strips a country of all its big vegetation.

Bawdwin was finally abandoned by the Chinese about 1868 as a direct result of the great Mahomedan rebellion in Yunnan.

The ancient Chinese mining and metallurgical methods are described at length in our earlier report (*loc. cit*, pp. 242-246).

It is said that after the final departure of the Chinese the Burmese kings Mindon Min and Theebaw sent "armies" to work the mines, but epidemic diseases and the ravages of a bad climate killed the colonists. It is very doubtful if the Burmese ever possessed sufficient mining or metallurgical skill to make a success of an ore deposit like that of Bawdwin.

From that time until the modern history begins, the huge slag heaps and the mines have lain undisturbed, except for the occasional visits paid by bands of Kachins who carried off the richer lead matte and smelted it in small furnaces with charcoal on the hills around, using the lead so produced for bullets. Small heaps of these re-treated slags are common in the country around the mines. According to Maclaren the mines were first brought to the notice of the authorities as the source from whence the Kachins drew their supply of lead.

From the records preserved in the archives of the Superintendent of the Northern Shan States at Lashio, I gather that Messrs. Sarkies Brothers of Rangoon were the first to apply for a Prospecting License over the area on January 8th, 1902.[1] In March of the same year the Taungpeng Sawbwa, when stating that he had no objection to the license being granted, said that he knew the locality in ques-

[1] Mr. A. C. Martin of Rangoon visited the mines in 1900 and was accompanied by Mr. Aviet T. Sarkies on his third visit to them in 1901 (*Min. Mag.*, Vol. XV, No. 4 (1916), p. 221)

tion, that silver was found there, and extracted many years ago in the time of his father. On April 22nd, 1902, the Lieutenant-Governor of Burma sanctioned the issue of a prospecting license for silver over an area of 16 square miles to Messrs. Sarkies Brothers, and on May 26th the prospecting license indenture was signed. On January 29th, 1903 the Lieutenant-Governor sanctioned the transfer of the prospecting license from Messrs. Sarkies to the Great Eastern Mining Company Limited the chairman of which was Mr. M. F. Kindersley. The prospecting license was extended for a period of one year in March 1903, and again in June 1904, a yearly rent of Rs. 48 being charged each year. But in the same year 1904, the Great Eastern Mining Company applied for a mining lease of 3·9 square miles at Bawdwin to extract silver, copper, lead and zinc, which was granted by the Government of India. Up to June 1905, according to the Administration Report of the Northern Shan States for 1904-05, they took no further steps and withdrew all their employees from Bawdwin, so that it seemed that the project had been abandoned or at least deferred. The same report for 1905-06 stated that it was understood that the Great Eastern Mining Company had been reconstituted and would shortly take steps to obtain the Bawdwin lease. In 1906-07 the new company known as the "Burma Mines Railway and Smelting Company Limited," which had purchased the interests of the Great Eastern Mining Company, who were unable to carry on their projects from lack of funds, obtained the Bawdwin lease for 30 years and made fair progress in the construction of the light railway from Manpwe, on the Lashio branch of the Burma Railways, to the concession, a total length of slightly over 50 miles.

In 1907-08, the name of the company was again changed to the "Burma Mines Company Limited." Disappointingly slow progress was being made with the railway, owing to labour difficulties and troubles from slips and wash-outs during the rains. Still, at the end of the period, 42 miles of rail were open, half of which was ballasted and half packed with earth. The bridge of 134′ span across the Nam Tu was about half finished. The transportation of the old Chinese lead slags by road for 2½ miles to a point where they could be shot on to the line was started. A tunnel was also commenced at Bawdwin to tap the mines below the level of the Chinese workings. The erection of the smelting plant to treat the slags at Mandalay Shore was completed.

In 1908-09, the bridge across the Nam Tu was completed; at the beginning of 1909 the railhead was at Tiger camp and it was completed to the main slag heaps at Bawdwin by the first week in December 1909. Up to this date the slag was brought from the mines to Tiger camp by mules and bullocks. The first slag was hauled over the line in December 1908 and from that time to the end of 1909, a total tonnage of 14,019 tons of slag and ore was delivered at Manpwe. The difficulties met with in railway construction are shown by the fact that between Tiger camp and Bawdwin– a difference in elevation of 500 feet in a distance of 2 miles as the crow flies– over 5 miles of track had to be laid down to get a workable grade, including a section of 2 miles running up the sides of Waller's gorge necessitating very heavy cuttings, some of which are over 70 feet high, and the use of two reversing stations. In the lower portion of the line the heavy rains caused bad wash-outs and the settlement of large banks, while the softness of the bed in the unballasted portion made the use of heavy locomotives impossible. In spite of these difficulties the first smelting furnace at Mandalay Shore was blown in on February 5th, 1909, and the second on February 8th. During the first two months the usual initial troubles were experienced, due mainly to the difficulty of obtaining suitable fluxes, but by the end of 1909, 12,762 tons of slag and ore were treated, of which 11,850 tons were Chinese slag from Bawdwin averaging 46·045 per cent. lead and 1·78 oz. silver, and 912 tons consisted of ore, 466 tons of which came from Bawdwin and the rest from the ill-fated Mount Pima mine and other sources. The calculated total lead content of the slag was 5,715 tons and the actual amount produced was 5,029 tons, a recovery of 88 per cent. In the first six months of the smelting the recovery equalled 88 per cent. but in the last 6 months it improved to 93 per cent. The total silver content of the slag and ore treated was 27,355 ozs. and the total silver content of the lead bullion produced amounted by assay to 26,398 ozs., or a recovery of 96·5 per cent. The total value of the silver and lead as realised in London was £57,222 or £4-9-8 per ton of the slag and ore treated. About 14 tons of nickel and copper speiss and matte were also accumulated. The coke used in reduction came from the Plean colliery in Scotland. During this year active developments took place at the mines. The Dead Chinaman Tunnel, which eventually was to reveal the great Chinaman ore body, was cleaned out and cut down to a workable size, to 324 feet in

from the portal, when the work was stopped owing to bad ventilation. An incline shaft was also started from the Quartz Tunnel with the idea of getting down under the Amphitheatre.

In 1909-10, a site was selected for the vertical shaft. A good deal of work was done in finishing off the railway and in providing rolling stock and shops. At the end of the administrative year in 1910, 21,558 tons of slag containing between 46 and 48 per cent. of lead and about 1·8 oz. silver were railed to the smelters; this includes some of the material mentioned earlier. The lead produced amounted to 9,423 tons containing approximately 44,658 ozs. of silver. The average value realised in London for the lead was £12-1-6 per ton and for the silver £0-2-2 per oz. Small amounts of low grade ore were also won from open cuts and old workings totalling 735 tons of ore containing approximately 18·5 per cent. lead and 13 oz. of silver per ton.

In 1910-11, the permanent way of the railroad was at last in good order. The vertical shaft was equipped with surface plant and enlarged. It has two hoisting compartments, a ladder and a pump way. Winding and steam plant were provided for the inclined shaft which was ventilated by two fans driven by a waterwheel. The total development work for the year amounted to over 2,000 feet and the winning of ore in the upper workings to provide a siliceous flux for the smelters was extended. 2,687½ tons of ore were mined, the average value of which was approximately 19·38 per cent. lead and 7·72 ozs. of silver per ton. 35,479 tons of slag containing 45·4 per cent. of lead and 1·78 ozs. of silver per ton were railed to the smelters at Mandalay. The smelters treated 67,888 tons of ore and fluxes during the period under report and produced 16,337 tons of lead, which averaged £12-19 per ton, and 81·685 ozs. of silver averaging £0-2-2½ per oz.

In 1911-12 (administrative year ending 30th June 1912), the smelters were removed from Mandalay to Nam Tu. The slags and ores smelted at Mandalay totalled 12,054½ tons and at Nam Tu 15,774½ exclusive of fluxes. A lead refinery was erected at Nam Tu. The railway line from Manpwe to Bawdwin was re-sleepered and ballasted, resulting in a material decrease of maintenance charges. Extensions were also made to permit trains to run to the vertical shaft and to the new smelter site and refinery. A number of Italians were engaged for mining work. The total developmental work done in the mine was 3,624 lineal and 8,159 cubic feet. The tonnage mined

was 5,568 tons of which a large portion was low grade iron ore only useful for fluxing. The company took over a prospecting license issued for the old Chinese mines at Mo-ho-chang about 35 miles from Bawdwin. A survey for a railway from Nam Tu to this place was in progress and a small smelter was erected near the mines to treat the lead slags left by the Chinese.

In 1912-13, the Chinaman lode was opened up on the 171′ level. Total developmental work equalled 6,127 lineal and 9,051 cubic feet. 6,222 tons of ore were mined and 32,019 tons of slag were recovered by sluicing in the Bawdwin valley. The 3rd level at 300 feet in the vertical shaft was opened up, and an adit level 1,860 feet long was finished to carry off the drainage from No. 1 level which was formerly pumped through the shaft. The total tonnage of slag and ore treated at the smelter was 37,254 tons containing approximately 80,000 ozs. of silver, the increase in silver being due to the larger proportion of ore now smelted with the slag. A turbo-blower for the smelters and a roasting plant with a capacity of 120 tons per day were added to enable the fine slag and ore to be desulphurized before going into the blast furnaces. Additions were made to the refinery and 3,132 tons of refined lead were sold in Rangoon.

In 1913-14 ending June 30th, 1914, the finances of the company were reorganised and the Burma Mines Company was taken over by the "Burma Corporation Limited." Great strides were made in opening up the mine both in the vertical shaft and Dead Chinaman Tunnel sections.

The developmental work for the year was 15,199 lineal feet exclusive of diamond drilling and 18,910 cubic feet. The vertical shaft was deepened to 437 feet with crosscuts at 102 feet, 171 feet, 300 feet and 430 feet. Total tonnage of slag, ores and fluxes treated in the smelters amounted to 51,482 tons yielding 6,872 tons lead containing approximately 175,906 ozs. of silver. The increase of silver is due to increase of ore smelted with the slags. 11,380 tons of ore were exported to Europe assaying 23·4 ozs. silver, 24·9 per cent. lead and 32·8 per cent. zinc. Tonnage of slag won during the open season was 36,430 tons, estimated to contain 37 per cent. lead and 6 ozs. silver per ton. At the smelters a brick flue chamber and chimney stack were built and arrangements made for an additional blast furnace and two round roasters. The small furnace

at Mo-ho-chang reached an output of 5 tons per day for part of the period.

In the year 1914-15, the Chinaman ore-body was opened up further and the mine prepared for stoping in the upper levels. The Tiger Tunnel was driven further and should be connected through to the Chinaman ore body by the end of 1916. The results of concentrating tests in the small experimental mill have proved sufficient to justify its enlargement to deal with 100 tons per day, which will result in the production of a rich lead concentrate suitable for treatment in the smelters in place of the old Chinese slags, the supply of which is now fast approaching exhaustion. The average production of hard lead for the half-year ending July 30th, 1915, was 1,125 tons monthly as against 706 tons monthly during 1914. The average production of refined lead derived from the hard lead per month was 457 tons, as against 324 tons during the same periods. Steps have been taken to smelt mixtures of roasted ore and concentrates estimated to produce about 1,500 tons of lead and about 140,000 ozs. of silver per month. A 1,000 horse-power Diesel engine and generator has been delivered on the mine to supply power.

GENERAL GEOLOGY.

Topography.

The Bawdwin district contains two types of sharply contrasted relief. West of the Nam Tu the surface is mountainous and entirely occupied by steep slopes produced by the erosion of many streams. Flat ground, either as plateaux or in valley bottoms is conspicuously absent, the nearest approach to it being the sinuous narrow tracts of alluvium which rarely border the banks of the larger streams. Even the larger valleys are deep and V-shaped, separated from one another by steep, knife-edged ridges, their sides scored by innumerable glens and ravines which make up the amazing net-work of the feeder drainage-system of the country. Dense, temperate evergreen forest generally clothes the hills from base to summit. In proportion to their length the streams possess high gradients and deposition is the exception rather than the rule. Yet regarded as a whole there is a certain uniformity of level about the principal crests, not indeed suggesting itself on a first glance at the country, but rather to be noticed by a study of the extensive views from commanding stations, with the help of the topographic

map. These higher features attain from 5,500 to 6,500 feet above the level of the sea. Does this uniformity of the crest lines of Western Taungpeng reveal the remnants of an old Tertiary peneplain, already known from various parts of Eastern Asia—the Pei-'Tai form described by Bailey Willis in Central and Eastern China, the Étage du Kiao-ting-chaun noted by Deprat in Eastern Yunnan,[1] or shortly, is the present intricate surface of this area only a direct consequence of prolonged river dissection?

East of the Nam Tu and extending a few miles to the west of the river in the Mong Tat neighbourhood, the true Shan plateau type of country is found, though here again the usual flatness is diversified by the deep valleys of the Nam Tu and some of its smaller tributaries. In these regions limestone is the prevailing rock, denudation proceeds more or less evenly, there are many underground streams and the surface is covered with open jungle with little undergrowth. There are no striking or rapid changes of gradient outside the river valleys already mentioned, the smaller valleys are broad and shallow, their sides gently sloping. The streams are sluggish and often entirely missing in the dry season. The deposition of travertine is exceedingly rapid, forming bars across the streams which flow in series of shallow and deep pools, or, again, raising the level of the stream-bed and causing the water to flow in a network of branching channels. A thick mantle of clayey soil covers the surface through which rock crops out at more or less isolated intervals.

The change from one type of scenery to the other is very abrupt and follows the boundary of the Plateau Limestone.

Drainage.

The dominant water-course of the district is the Nam Tu which enters it from the east and follows a westerly course towards Mong Tat. Near its junction with the Nam Yi it turns to the south-west and follows this direction to the neighbourhood of Mong Hseng, whence it flows south and south-east to the Ta-mawng-tawn ferry, where it is crossed by the main trade route between Nam Tu and Mong Yin. Here a sharp bend brings the river round to Nam Tu

[1] Bailey Willis : Research in China, Vol. 2, pp. 96-113.
J. Deprat : *Mems. du Serv. Geol. de l'Indo Chine.* Étude géologique du Yunnan oriental, Vol. I, Fas. 1.
J. Coggin Brown : Geology of the country around Yunnan Fu. *Rec., Geol. Surv. Ind.*, Vol. XLIV, p. 118.

(Panghai), where it is crossed by the bridge of the Burma Mines Railways, thence it pursues a south-west and south course out of the district. The Nam Tu is a large stream with a big flow of water liable to sudden rises in the rainy season. For long stretches it flows quietly in deep reaches but these are frequently broken by rapids which make continuous boat navigation an impossibility. At least five of these rapids occur in the district,—two miles to the south of Nam Tu, one mile above the same place, below its junctions with the Nam Pao and Nam Yi, and one mile above the confluence with the latter river towards Nakeng. The principal tributaries that enter the Nam Tu within the district on its left (north) bank are the Nam Pao which drains the limestone country in the extreme north-east and has all the characteristics of a small river flowing over limestone, the Nam Yi with its tributary the Nam Tat both rising north of the district and flowing for the greater part of their courses in it, across limestone. The Nam Krak is a small affluent of the Nam Tat. Further to the south, the Nam Tu receives the Nam Hseng, itself produced by a complicated stream system which includes the Nam Tup, Nam Sing, Nam Kabo, Nam Hkung and Nam It; and the Nam La, near the mouth of which the town of Panghai or Nam Tu is situated; the Nam Maw or Pangyun (or Stern River as it is called by Europeans), draining the Bawdwin valley, a small perennial stream whose turbulent waters are now full of mud and dissolved lead salts from the slag sluicing in its higher reaches. The only other important stream is the Nam Kung with its tributaries the northern and southern Nam Pungs, the Nam Hupat, the Nam Leng and the Nam Ham, Nam Wan, Nam Parak, Nam Pratep and Nâm Ai. Most of these are merely mountain torrents, flowing swiftly down the granite slopes of Taungpeng. In addition to these the Nam Sin, Nam Un, Nam Po and Nam Kwoi head in the district but join the Nam Tu further south. On the south bank the Nam Tu receives the Nam Hsai and the Nam Sangpo with its tributary the Nam Pong. These are all small streams almost dry in the summer, draining limestone areas. The Nam Pai and the Nam Un head in the south-east corner of the district. The Burma Mines Railway follows the course of the former for some distance.

In addition to these streams which like the Nam Tu itself are liable to sudden rises after rain and are then impossible to cross until the spate has subsided, a glance at the map will show a most intricate network of almost innumerable smaller torrents and rivulets

fed mainly by springs. In the western part of the district the drainage flows north-west and west into the Shweli. Here rises the Nam Meit with its tributaries the Nam Kan, Nam Pya, Nam Taw and the Nam Saing which receives the Nam Wun, Nam Pong, Nam Tao and Nam Palit.

With the exception of the limestone area, the valleys of all these streams are very narrow and there is little cultivable ground in them. The Stern River or Nam Pangyun is the best known and is more or less typical of them all. Its valley becomes very constricted and cañon-like when passing through the hard sandstones of the Nam Hsim series, broadens out a little in the softer Naungkangyi rocks, and becomes a deep gorge again when it enters the Bawdwin rocks near Tiger Camp. There is no room even for a railway along the bottom of this gorge and the engineers found it easier to blast a line high up above the stream.

Principal Features of Relief.

The highest land in the district is the big ridge which separates the Nam Tu drainage from that of the Shweli. It runs north from Loi Taungkyaw (7,470) and Loi Panghka (5,745) to Loi Ngulin on the west of the Man Ton valley. Save where it is breached by the Nam Pratep, one of the larger tributaries of the Nam Kung at an elevation of 4,133 feet, this great ridge preserves a uniformity of height varying between 5,000 and 5,500 feet, which is very remarkable when its knife-edged character is considered, for in some places along its summit, the statement that there is barely room for a mule track is literally correct. The small feeder streams drain close up to the top on both sides. A short ridge runs east for 6 miles from Loi Taungkyaw (7,470) to Loi Pangyok (6,721) the spurs of which divide the Nam Kung valley from that of the more southerly flowing Nam Tu affluents. This main ridge with the peaks Loi Taungkyaw and Loi Pangyok and the smaller subsidiary one, Loi Marow (5,614), (a spur sent out by Pangyok northwards for 6 or 7 miles parallel to the main northerly ridge), practically enclosed on four sides by the Nam Wan, Nam Kung and Nam Ham, closes the landscape as seen from the hills above Bawdwin looking to the west and southwest across the deep Nam Kung valley. From this distance their forest-covered and ravine-scored sides are toned down and the eye—no longer bewildered by a close and overpowering detail, sees a great stretch of country moulded into a relief as intricate as any

over seen in a "bad lands" country—though there of course the resemblance ceases. In these regions the mean elevation of the Nam Kung may be taken as 2.300 feet. The main ridge—5,000-5,500 feet—is only 5 or 6 miles away as the crow flies. The western versant of the range displays much the same features though here they are not so evident owing to the longer spurs thrown out in this direction. Such ridges trend south-west and north-east as exemplified by the one which separates the drainage of the Nam Long from the Nam Tao, and on which the villages of Man Sak and Tun-pang are built, or west like the big ridge running from Ho-mong through Ho-hpong to Mang-u in Mongmit. To an observer on an elevated point in the south-west of the district the main divide itself is somewhat obscured by these short branching spurs each separated by narrow and very deep valleys. The high range in the extreme south-west of the district, running from Namhsai Hkao (5,860) north-west through Loi Kateng Kolong (5,421) to the Ho-mang peak (4,819), commences at Nam Hsan (5,847), the capital of the State, 4 miles south of Aram. Striking as are the contrasts presented by this network of hill and valley, they are quite overshadowed by the imposing peaks of the Mogok district rising high above the Mongmit valley, which can be discerned easily from the higher lands in the west of the Bawdwin district. The highest land north of Bawdwin is found in the peak Loi Mongmong (7 067) which like most of the ridges already mentioned is composed of granitic rocks. The complicated stream systems forming the head-waters of the Nam Hseng take their rise in this peak and are separated from each other by short spurs having a general north-west and south-east trend. The hard rocks which form the belt of Silurian sandstones running partly across the district from the south to the north-west, attain heights of between 5,000 and 6,000 feet, but become lower towards their termination. Similarly well marked, by reason of its abrupt elevation above the flatter limestone areas, is the eastern Silurian zone which towards the south forms the high cañon wall bounding the Nam Tu on that side. The Bawdwin rhyolites and some of the harder grits of the Pangyun system reach elevations up to 4,700 feet, though as a rule the peaks average nearer 4,000 than this. They bear no particular relation to one another and appear to be very largely the result of general denudation and stream action on rock systems of varying resistive powers. Towards the north of

Bawdwin the three picturesque peaks of Mohotaung—unnamed peak (5,234) and the Penglun peak (5,557)—are composed of Plateau limestone and are of bolder outline than any others in the district. Their alignment may be due to the Bawdwin overthrust which bounds them on the west. They too are overshadowed by the most conspicuous feature of the landscape around Bawdwin, the great peak of Loi Kyauktaw (6,198) miles to the north.

The eastern portion of the district has a much less accentuated topography, the highest points on the Plateau Limestone seldom rising above 3,000 feet, the average elevation of this somewhat featureless area being about 2,500 feet. The highest point on the map is Loi Taungkyaw, elevation 7,470 feet. The lowest is that at which the Nam Tu leaves in the south. Here the elevation is not more than 1,700 feet. The difference—5,770 feet— gives a good idea of the great variety of relief which exists.

STRATIGRAPHY.

General.

The Bawdwin ore deposits are enclosed in a series of ancient rhyolites and rhyolitic tuffs which form a kind of dome-shaped structure protruding through the younger Pangyun strata. Going west, an overthrust band of Nam Hsim sandstones is crossed before the rocks of the Chaung Magyi series are reached. These form an ancient land surface and with their associated intrusive granites build up the highlands of Tawngpeng. The younger Palæozoic rocks found east of Bawdwin and especially well exposed in the gorge of the Nam Pangyun were deposited in succession on the old land surface. They succeed one another in ordered sequence Cambrian (?), Ordovician, Silurian and Devonian, and have been traced northwards from the neighbourhood of Hsipaw, forming a broad belt along the valley of the Nam Tu. The following rock groups have been met with in the Bawdwin district :—

	European equivalents.
Recent alluvium	
Sub-Recent River Terraces	
Nam Yau Series	Jurassic.
Plateau Limestone	Devonian.
Nam Hsim Beds	Upper Silurian.

	European equivalents.
Pangsapye Graptolite Bed	Llandovery.
Naungkangyi Beds	Ordovician.
Pangyun Beds	Ordovician or Cambrian.
Bawdwin Volcanic Series	
Chaung Magyi Series	
Tawnpeng granite and associated intrusives .	

I shall now describe the various groups in detail.

The Tawnpeng Granite.

The Northern or small map intrusive granite of Tawnpeng forms most of the higher country west of Bawdwin. The rock is an ordinary white granite, consisting of quartz, orthoclase, microcline and biotite. It usually bears evidences of intense crushing. La Touche's statement that it contains no tourmaline is incorrect as later work has shown that tourmaline does occur in it though quite sporadically. It is difficult to obtain fresh specimens of the rock as it is nearly always exceedingly weathered. Basic intrusions of diorite and olivine gabbro are quite common in it. The latter is composed of olivine in large grains with a peculiar violet-brown tint, andesine or labradorite and a colourless augite which often surrounds the olivine and felspar. The eastern boundary of the granite sweeps round towards the north-east beyond the regions shown on the map and builds up the high country around Loi Mong-Mong, 10 or 12 miles north of Bawdwin as the crow flies.

The Chaung Magyi Series.

This, the oldest sedimentary formation of the district occupies a wide extent of country in the western area, coming between the Tawnpeng granite on the west and the Palæozoic rocks on the east. Its inner border with the granite is a very irregular one owing to the intrusion of a large tongue of the latter in the neighbourhood of Loi Ma-raw. The series consists of soft, well foliated, slaty shales, phyllites and greywackes with subordinate sandy horizons and although it forms much of the highest land it yields exceedingly few good exposures. Indeed it is difficult to find outcrops of any kind as a rule, except in stream-beds or recent cuttings, while folding

and faulting add greatly to the difficulty of working out the detailed stratigraphy. The western boundary of the series enters sheet $93\frac{E}{1}$ to the west of Aram, continues north until it is almost a similar distance west of the peak Loi Tawngkyaw, itself built up of these same rocks, and thence curving around the northern spurs, turns again to the west. This direction with minor alterations is continued as far as Ho-hkün when turning completely back on itself in an eastern and south-eastern direction, the boundary continues for several miles around the head of the Nam Wan, to the north-east again and thence north-west past Hai-tawng to Ho-mong. From this place an approximately north and north-east line is followed until the Nam Kung is crossed, whence the direction abruptly changes east and north-east across the Nam Sing valley on to sheet $93\frac{E}{5}$. On this sheet a band of Chaung Magyi rocks some 3 miles broad is found in the north-west corner.

Owing to the paucity and great discontinuity of outcrops, the presence of a dense vegetation and thick soil, no estimate of the thickness of the series in the district can be attempted and no subdivision of the rocks themselves made.

The eastern boundary which separates the Chaung Magyi from the overlapping band of Nam Hsim sandstones enters sheet $93\frac{E}{8}$ about two miles to the south of Manoi, and after passing close to this village, continues in a general north-western direction into the valley of the Nam Kung. The Nam Hsim beds are probably cut out by a cross fault in the neighbourhood of Hinpok, on sheet $93\frac{E}{5}$, after which the inner boundary between the Chaung Magyis and the Pangyuns follows parallel to the outer one.

Lithology.—On the main road *viâ* the Nam Kung, from Nam Tu to Nam Hsan, the capital of the State, the Chaung Magyi rocks are first met with near Man-oi, as typical greyish slaty shales in very poor exposures, often bleached in colour and containing much vein quartz. Where the road crosses the Nam Un stream grey slates with a high eastern dip strike north and south and are followed by striped reddish and bluish-grey to violet slates weathering into soft mudstones, in thin and rapidly alternating bands of colour. Immediately outside Hkö-hkün they dip south at about 40°.

The great band of Chaung Magyi rocks which crosses the western part of the Bawdwin area is composed of the same types of slates and greywackes with a few sandy horizons here and there ; exposures are poor and very infrequent, partly owing to thick forest covering

the rocks everywhere, and in a greater measure perhaps to their softness and the ease with which the fresh material is buried under thick masses of clay resulting from their denudation. A few of the more important outcrops are described below.

Near the large pagoda to the west of Ho-hkun, a dark bluish-grey silvery phyllite with subordinate bands of a fine-grained pinkish white quartzite strikes west-north-west, east-south-east and dips towards the south at 48°. A few yards further west another exposure gives a strike of north-east—south-west. Under the microscope the phyllite shows abundant minute grains of graphitic matter and quartz together with very numerous small flakes of a colourless sericitic mica, parallel to the cleavage of the rock, which is very well developed. The quartzite contains abundant irregular quartz grains, both large and small, together with much opaque yellowish-brown, ferruginous matter.

The Chaung Magyi rocks to the north of Bawdwin are of a slightly different facies and sandy layers are perhaps commoner. For example on the route from the Nam Kabo through Kawng-mu to Tun-hsai, at first exposures are exceedingly scarce after leaving the greenish-grey slates in the bed of the river, which are supposed to belong to this series. But after crossing the Nam It greenish slates predominate, with an occasional bleached purple or reddish horizon and a sandy bed now and then. The dip above the Nam Hkung is 13° east; up the high ridge which separates the Nam Hkang and the Nam Kabo, fine-grained greenish-grey sandstones or sandy shales often of reddish shades at the surface; bleached reddish-purple, arenaceous shales and greyish-yellow weathered argillites are seen in a few poor outcrops. Further up the ridge the intrusive Tawngpeng granite is found, but neither this locality in particular nor the area generally is a good one for studying any phenomena of contact metamorphism which may exist. The poverty of visible rock makes it quite impossible to work out any changes which may have occurred, as the Chaung Magyis cannot be followed for more than a few feet at a time. The soft weathered slates and argillites which are seen have nothing to distinguish them from the same rocks elsewhere.

Bawdwin Rhyolite Series.

The elongated irregular area occupied by these rocks has been carefully mapped and found to comprise a narrow strip of country

running in a general north-west and south-east direction. From Tiger Camp to the point in the upper Stern Valley where they finally disappear beneath the Pangyuns is not more than three miles, in a straight line. The series consists of true rhyolites, rhyolitic tuffs, true tuffs of various kinds, an occasional band of volcanic breccia and subordinate layers of sandstone and felspathic grit. I regard the whole exposure as a kind of low dome rising from underneath the Pangyun beds, which surround it on all sides. The main axis of the dome runs north-west—south-east. It is not always easy to separate the base of the Pangyuns from the uppermost beds of the Bawdwin Rhyolite series, for the Pangyun conglomerate is always succeeded below by shales and grits—certainly of no great thickness, but still almost identical with those above it. Many of these lower Pangyun felspaltic grits contain much tuffaceous matter and again the uppermost tuffs of the Bawdwin series are often gritty. Added to this, the general silicification of both groups further complicates a possible distinction. But these passage beds are not thick and the conglomerate or coarse grit, as it sometimes is, gives a good indication of where the junction is to be looked for. The base of the Rhyolite series is not visible but judging from other parts of the Northern Shan States they may be expected to overlie the Chaung Magyis unconformably.

The rhyolites, which are subordinate in quantity to the tuffs, are pink, brown or chocolate in colour and often full of clear grains of secondary quartz. The best exposures of true rhyolite are found in the west of the area occupied by them. For example they may be seen cropping out at intervals all along the Loi Mi valley to within 300 yards of the top, where they are overlain by purple Pangyun shales. In the Goldhole valley, the tuffs occupy the lower ground and the rhyolites the upper. Here they are pinkish-grey rocks speckled with rust stains, dark spots and blebs of clear quartz. They always carry a thin skin of brownish decomposed material on the outside. As these rocks weather further, strings and patches of brown ferruginous matter make their appearance, the groundmass becomes lighter in colour, patches of chlorite are developed, until, eventually, the secondary quartz grains appear to be the only unaltered mineral left. The rhyolites on the east side of the E. R. valley form a series of well-marked small cliff exposures which strike towards Mount Teddy when viewed from the Amphitheatre. The volcanic breccia of Mount Herschell crops out in

great masses on the grassy hill-side and can be seen from considerable distances. It is a purplish-grey rock speckled with white, containing much secondary quartz and large included fragments of rhyolite.

Flow structure is occasionally seen in hand specimens of the rhyolite, but usually a section is required before it can be made out. Typical rhyolites occur underground in Tiger Tunnel but they are here very smashed and broken by fault planes. Another band of volcanic breccia was met with when sinking the vertical shaft, but as work had been temporarily abandoned there I was unable to see it *in situ.* Specimens from the dump were of a dark greyish-green colour and slaty inclusions were common. It also contained abundant blebs of clear secondary quartz, together with strings and patches of a dark brown siderite. Sometimes this rock is full of cavities left by the removal of some constituent—perhaps felspar. Again it may be exceedingly broken up and made of angular fragments loosely held together—an indication of the great strains to which it has been subjected. Finer-grained varieties occur which are greyer in colour, with fewer and smaller shale inclusions and a greater development of secondary quartz. In Tiger Tunnel lumps of graphitic slate are rarely found included in the rhyolites. Other patches of rhyolite occur both to the north and east of Bawdwin, near Hsun-oi and Lao-ka-ya and also in the Nam La valley. They are of small extent and have not been accurately mapped.

Tuffs.

The tuffs form by far the greater part of the series and are of first importance because in them the ore bodies have been deposited. Though undoubtedly of clastic origin, they have undergone such extensive metamorphism that it is not always easy to say where the rhyolite ends and the tuff begins. As already pointed out they are not always easily distinguished from the felspathic grits of the Pangyun series. At the surface, owing to kaolinisation they are usually soft and of a light greyish colour. Underground they are darker and often honey-combed, though here their original nature is still further masked by the chemical changes they have undergone through the action of mineralising solutions.

The tuffs form the high ridge which borders the E. R. valley on the west and separates it from Waller's gorge. Commencing on the north-west slopes of Mount Battle, where they are overlain

by the Pangyun sediments, they build the high peaks of Mount Costin, Rolls, Lakeland and Teddy. On the top of the latter a very decomposed chloritic variety occurs, which becomes more gritty towards the bottom and contains spherulites and small shaley inclusions. It also contains thin quartz veins in places, and the joint planes of the rock are sometimes filled with the same mineral.

Good exposures of the weathered tuffs can be obtained along the Burma Mines Railway where it crosses the extreme south-eastern limit of the Rhyolitic series. Near the mouth of E. R. valley they are smashed, folded and contorted by faulting. Near mile 48, soft decomposed rhyolites of a purplish-grey colour, spotted with ferruginous stains are seen. A thin band of sediments follows at 48-1 consisting of purple slates with a few sandstone layers and is underlaid by the mass of the tuffs again. About 18-2 these are soft and very decomposed, the background of the rock is white with purplish spots and small patches of a bright green chlorite. Occasionally the outlines of the felspar crystals now replaced by a pure white kaolin are seen. At 48-4 a greenish-grey banded variety occurs, and at 49-6 chlorite inclusions are common. The sediments start at about 49-1 but in the 49-2 stretch there are a few tuff exposures too small to be mapped, very intermixed with the sandstones and shales which at this point attain their maximum disturbance. Reversed folding was seen at one place.

In the E. R. valley chloritised tuffs with much secondary quartz contain cubes of limonite, pseudomorphous after pyrite. Banded grey tuffs, with faint lines of stratification, somewhat chloritised and excessively kaolinised, containing honeycombed layers produced by the leaching out of the decomposed felspars, are common. They are very similar to certain varieties found underground. There is an old adit in them just beyond 48-5. Near 48-4 a greyish chloritised variety carries small speaks of chalcopyrite. The tuffs are followed by purplish rhyolite flows and then by sediments of the Pangyun series near that point on the line where Tiger Camp is first seen. A band of very altered rhyolite near the crossing of the E. R. valley contains spherulites, which were also found in decomposed rock on Mount Teddy.

Fresh exposures of the same rocks are seen in the bottom of the deep S. gorge which is more or less parallel to the railway across the sections already described. Some of the tuff boulders in the

bed of the stream have a well-developed banded structure and contain inclusions of chlorite up to 4 inches in length. When first met with the tuffs dip at 20° east and form both sides of the gorge, but before long the dip veers more to the east and north-east and becomes higher. A little further up stream the rocks on both sides of the gorge become quartzitic, or those brownish-grey grits which form the junction between the Pangyun and the Rhyolitic series hereabouts. These rocks are intensely shattered and their fresh surfaces are traversed in every direction by secondary cleavage planes. Below the point where the E. R. valley stream joins the S. gorge I found a tuff with films of malachite, which I regard as the weathered representative of the chalcopyrite-bearing tuff of the railway section. Again, a few yards above the junction, near an old Chinese working, there is a heap of tuff carrying small amounts of galena, while the rock *in situ* is stained with copper salts. About here the intense crushing has resulted in an intimate interfolding of the sediments and the tuffs and there is a change from one to the other every few yards. No definite boundary can therefore be drawn. Evidently the main line of faulting passes through the S. gorge somewhere about this point.

In the vicinity of the mines themselves at Bawdwin, mineralization and weathering have masked the original characters of the tuffs to a considerable extent. Thus, from the neighbourhood of the vertical shaft to the Amphitheatre, on the east side of the stream, they are changed into a ferruginous gossan consisting of a rotten limonitic rock or rarely a white kaolinized grit, the last products of decay, containing films and nests of oxidised lead and copper compounds,—anglesite, stellate twins of cerrussite, malachite and azurite. This material is quarried for use in smelting slags, but rather for its silica than its iron content. Thin bands of silicified tuff also occur under the gossan, but they are often separated by layers of a light brown powdery limonite up to 4 or 5 inches thick. Between the Robey compressor station and the vertical shaft, the surface of the east bank is very dissected by rain denudation and old workings, and the tuffs are represented by a soft ferruginous material in which the original structure can scarcely be seen. It is an exceedingly altered rock.

To the north of the gossan quarries, white kaolinised tuffs crop out. In places they are recemented by ferruginous matter and then have the appearance of fault breccias. In the Dormouse ravine,

the tuffs carry galena and oxidised lead minerals at the surface. Incrustations of sulphates of copper and zinc are also present on overhanging, unexposed rock surfaces.

On the dumps of the vertical shaft hard fresh pieces of dark grey tuff often bear slickenside planes. The commonest variety here is a mottled, greyish-white to grey rock flecked with pale yellowish-green chlorite, speckled with glistening crystals of galena and containing sideritic inclusions often of almost circular outline. In one specimen I noticed a large piece of quartz pseudomorphous after a felspar crystal. Occasionally the chlorite is developed on a large scale and then appears as bent and strained pieces up to an inch in length, of various shades of green. Rarely, small spots of hematite occur in the tuffs.

Underground tuffs.

The honeycomb tuff found underground is of a white or greyish-white colour, friable and so full of holes as to resemble pumice: specks of chlorite are sometimes found in it.

The white kaolinised tuff from the upper levels of the mine weathers down on exposure at the surface into heaps of white clay studded throughout with small pieces of quartz.

A large number of slides have been prepared of both the rhyolites and tuffs but the detailed petrological description of these was not completed when I was deputed to the wolfram mines in Tavoy. This investigation must now be left to some future occasion but it may be pointed out that the rhyolites exhibit the usual phenomena observed in acid lavas which were originally glassy, the quartz mosaic structure being especially characteristic. The tuffs do not differ very greatly from the lavas except that they do not exhibit any fluidal structures but are distinctly clastic in origin and their alteration is more profound.

I am inclined to associate the Bawdwin volcanic series with the oldest Palæozoic rocks rather than with the Chaung Magyi series, for unless the conglomerate horizons found in North Valley mark a stratigraphical break of some consequence—and I regard them as strictly local in their distribution—there appears to be a gradual passage down from the lowest Naungkangyi beds through the Pangyuns into the Bawdwin tuffs and rhyolites. Wherever the rhyolites have been found in other parts of the Northern

Shan States they invariably occur between the Chaung Magyi strata and the lowest member of the fossiliferous series. I do not think they are continuous over great distances, but rather that they were formed at various isolated centres and in most cases are more or less completely overlapped by higher beds.

Pangyun Beds.

In an unpublished manuscript report written in 1906, Dr. J. M. Maclaren described under the title of "Banyan Beds" a series of "fairly thin-bedded rocks made up of red and white sandstones chocolate micaceous shales and quartzites with subordinate dark shaly beds and occasional conglomerates" occurring in the immediate vicinity of the Bawdwin mines. He was able to prove that they were younger than the rhyolites and the series to which he gave the name of the Bawdwin beds. Maclaren also described an unfossiliferous series below the Naungkangyi beds to the west of Lopah in the valley of the Nam Pangyun, "at first sight" he writes, "they would appear to underlie the latter, but they are so very much fresher and younger in lithological appearance that the final impression left in the mind is that they are much younger than the Naungkangyi beds." He regarded the two sedimentary series, the Bawdwin and Banyan beds, as being very closely connected—the latter overlying the rhyolites unconformably. Regarding their age he writes "The sedimentary members probably occupy a horizon in the Ordovician or may possibly be Upper Silurian. The solution of the question is not practicable from the single section run by the writer."

La Touche in 1909 drew attention to unfossiliferous, fine-grained, reddish-brown sandstones, not easily distinguishable from the Nam Hsim sandstones to the south, which succeed the older rocks, coarse felspathic grits and rhyolitic tuffs with thin flows of true rhyolite: "The sandstones are found extending for some 4 or 5 miles along the gorge of the Nam Pangyun below Bawdwin with a regular easterly dip, until they disappear beneath the Naungkangyi shales. In addition to the grits there are found in the immediate vicinity of Bawdwin patches of quartzitic sandstones and shales, with which is associated, some miles to the west of the mines, a band of coarse conglomerate. It is extremely difficult to make out the relations of these beds with the grits and rhyolites, but the pro-

bability is that they are outlying patches of the Nam Hsim sandstone series, folded or faulted down among the older rocks."

In proposing the name Banyan Beds for the rocks which overlie the ore-bearing series of Bawdwin, Maclaren carefully explained that it was only intended to possess a local meaning, and the time has now come when it must be superseded by a term more in keeping with the importance and with the extension which the rocks have been found to possess. Instead of the term Banyan Beds I therefore propose the term Pangyun beds derived from the name of the valley in which the best continuous exposures of the rocks have been found. The Nam Pangyun is the stream forming the narrow drainage gorge up which the Burma Mines Railway runs from Nam Tu to Bawdwin. The series is in absolute conformity with the fossiliferous Lower Naungkangyi above it and passes down without a stratigraphical break of any consequence into the Bawdwin tuffs and rhyolites below it. Its age is either Lower Ordovician or Cambrian but as it is quite unfossiliferous, as far as present knowledge goes, this point cannot be decided definitely. It is convenient to describe the Nam Pangyun valley section and the Bawdwin exposures first. There is a prevailing high easterly dip up the Nam Pangyun valley, and after entering it at its junction with the Nam Tu, the Plateau Limestone, Nam Hsim sandstone, Pangsapye beds and Naungkangyi beds are successively crossed in descending order. About 300 yards beyond Lopah station on the railway, the last fossiliferous bed in the Naungkangyi section is passed and the underlying Pangyun sediments immediately encountered, as purple shales and thinly bedded purple sandstones which strike north 20° west and dip easterly at 30°.

They are followed between miles 41-3 to 11-5 by dark reddish-purple, ripple-marked sandstones dipping at high angles to the east and often interbedded with more shaly horizons. At mile 45-1 coarse quartzites and grits containing tiny nests of malachite and azurite, dip east at 15°. At the loop on the railway, hard, light-coloured grits spotted with ferruginous grains are found, together with purple quartzites and shales with micaceous partings. Very crushed and rolled greenish-white quartzites occur in the first ravine above Tiger Camp.

At the entrance to Tiger Tunnel, contorted alternating bands of hard quartzite and purple shales dip 35° east. The former rocks are usually of a greyish-green or greyish-purple colour, well

jointed, and in certain cases broken up into small cleavage fragments. The joint planes are often curved and marked with horizontal slickenside grooves as though lateral, shearing movements had produced them. One set of the grooves coincides with the north and south strike. In addition to these dense white, greyish and greyish-purple quartzites, there are other varieties occurring in smaller quantities between Tiger Camp and the mouth of Waller's gorge where the dip is east at 35°. Among them the following may be mentioned:

(1) a hard greyish rock flecked with mauve and green speckles;
(2) a dense chocolate quartzite with reddish inclusions and films of sericite on the joint planes, along which it easily splits;
(3) a greenish chloritic quartzite;
(4) greenish-grey quartzites with reddish spots and clear grains of secondary quartz. This rock sometimes contains thin veins of calcite.

Just above the mouth of Waller's gorge there are outcrops of rhyolitic grits bearing specks of chalcopyrite. They are of a greyish-green colour with pink rhyolitic patches. Below Waller's gorge greyish-white quartzites occur, abundantly spotted with brown limonite—perhaps the remains of pyrite crystals. In them there is a thin band of coarse conglomeratic grit, containing small rounded pebbles of a pink rhyolite set in a greenish matrix, and grains of transparent secondary quartz. The quartzites themselves still contain a few slaty bands of greenish-grey tints but they are very subordinate. and occasionally, small greenish shaly fragments are included in the quartzitic matrix.

It is very probable that the rhyolitic conglomeratic grits correspond in age with the conglomerates of the North Valley.

In the immediate vicinity of Bawdwin the Pangyun sediments are much thinner-bedded than they are between Tiger Camp and Lopah, and there are more alternations of quartzites and shaly slates, especially on the north of the volcanic mass. Along the railway below Bawdwin, fine-grained purple slaty shales, fine-grained greyish-green micaceous slates and greyish quartzites with a tinge of purple are the commonest rocks. As a rule the slate bands only form layers a few inches thick between the quartzites.

and the latter very often develop ferruginous spots. Owing to local contortion the dip varies a great deal. Above the first small valley near mile 49-3 it is nearly 20° towards east 20° north, near the valley it is 60° in the same direction, but within 50 yards severe folding produces a vertical and even westerly dip in small folds exposed in the cuttings. In mile 49-4 the same purple and greyish-green slates strike north 20° west, but here again they are very disturbed and dip from vertical to angles of 60° and 70° both east and west. Immediately after crossing the stream the strike alters to east 25° south, west 25° north and the dip to 45° southerly taken on the same purple slates, the surfaces of which show a coarse kind of spurious ripple-marking which is brought about by contortion.

Fifty yards above the portal of the Dead Chinaman Tunnel, purple slates and hard white quartzites dip south at 65°. Opposite Bawdwin station the strike is still about 10° south of east and the dip high to the south with sharp folding. The axis of the folding is perhaps running north-north-west—south-south-east. At the mouth of Herschell valley thin bands of purple slates and hard brownish-grey quartzites strike north 30° east—south 30° west and dip east-south-easterly at 40°-45°. A coarse light greenish-grey grit is common about here, simulating the kaolinised tuffs of the lower group. These details are given to show the extreme distortion and fracturing of the Pangyun beds in the neighbourhood of Bawdwin—a result of the Bawdwin overthrust. At the waterfall on the Banyan tree track there is a fine exposure of one of the lower beds in the Pangyun group. This is a hard greyish-brown, coarse grit full of small grains of transparent quartz. It dips east at 20°-25° and strikes north and south. The rock contains occasional small pebbles of a brownish quartzite, but it is not a true conglomerate. Both above and below it the usual purple or greyish-green micaceous slates and purple quartzites are found. The general lie of the Pangyun beds at Bawdwin is much better appreciated when one bears in mind that the Nam Pangyun from the mouth of Herschell valley down to S. gorge is flowing along a synclinal axis, the dips on the north-eastern side being much steeper than those opposite.

Important sections of the Pangyun beds occur in North Valley, the name given to the upper part of the Nam Pangyun valley above Bawdwin. About two hundred yards north-east of Boundary

Valley a conglomerate crops out, but as purple slates and quartzites occur below it, it cannot form a true junction horizon between the Rhyolitic series and the Pangyuns. It is a dark-reddish-purple rock containing not only quartzite pebbles but rolled pieces of true rhyolite, while the cementing material is distinctly rhyolitic in character. It also contains clear quartz pebbles derived from the rhyolites. The quartzite and rhyolite pebbles are up to two inches in diameter and more rarely larger. The upper part of the outcrop is gritty like the grits found near Tiger Camp and I anticipate that these two horizons will eventually be proved to be the same. A fine-grained speckled grit above the rhyolite dips east at 30° and strikes north and south. It is followed by a second conglomerate band which contains more rhyolite pebbles than the first. Two other bands of the same rock are found between this point and the small outcrop of true rhyolites on the Hinpok road.

Good exposures of the Pangyun sediments are obtained on the track which leaves the Goldhole valley for the Nam La valley and Möng Hseng. At first, purple slates and sandstones are seen, with a low dip to the north and north-east. At the bottom of the valley, just down stream below the junction of the two tributaries which form the head waters of Waller's gorge, the junction of the Pangyuns and the rhyolite is found. The last rock of the first series is a grit containing pink felspathic patches, secondary quartz blebs and ferruginous spots. It is followed by a white ashy rhyolite exhibiting good flow structure. On the other side of the rhyolite band the commoner Pangyun rocks are purple and greenish slates and quartzites which in places contain thin quartz stringers.

Along the road from Loi Maw to Lao-ka-ya purple grits sometimes with a rhyolitic matrix, speckled grits, purple, green and bleached slates and fine-grained quartzites are found. To the north of Bawdwin along the Lao-ka-ya road, very similar rocks occur, though grits of the Tiger Camp variety are common.

Naungkangyi Beds.

The Pangyun series passes up conformably into the Naungkangyi beds of Ordovician age and there is some difficulty in finding a horizon to map as their junction. I have taken it as the top of a thick series of sandy purple mudstones which underlies the last Naungkangyi fossiliferous shale. In stream-beds where continuous

sections are met with, this horizon is not so difficult to find, but in other situations the line taken is more or less arbitrary, for exposures are few and far between. In the Nam Pangyun valley, along the track of the Burma Mines Railway, the greenish fossiliferous shale about ½ mile above Lopah station, is at once followed up stream by the sandy purple shales with the thin sandstone partings of the Pangyun beds. But down stream or further up into the Naungkangyi series, for there is a very prevalent easterly dip, brownish, red or chocolate sandy shales are found which contain beds with fragmentary remains of stunted brachiopods and cystidean plates. Near mile 43 they are false-bedded and dip south-east at 35°. Dark greyish sandy marls which very quickly weather down into a soft clay on exposure, with slightly harder and lighter bands, occur at mile 41-3½.

As the map shows, the Naungkangyi band enters from the south and strikes north. It is about 1½ miles broad at first, becomes wider in the Pangyun valley gradually thinning out towards the north-north-west before it finally disappears below the overlying Plateau Limestone in the Nam Krak valley. In most of the places where I have crossed this band I have succeeded in finding characteristic Naungkangyi fossils; for example, along the Sawbwa's road from Bawdwin to Nam Tu, just where the final descent to the railway commences, typical yellowish and reddish-brown marls occur crowded with fossils, cystidean plates and *Rafinesquina* sp. being the commonest.

Again, on the main road from Nam Tu to Nam Hsan down the right bank of the river, the Naungkangyis are exposed as reddish-purple mudstones striking north and south and dipping to the east, with harder marly bands. Towards the Nam Kung they become very sandy and below the bridge across this stream contain massive, reddish-purple sandstones with ripple-markings. Ascending the other side the sandy beds are followed by bleached brown marls containing *Strophomena* sp. and other fossils. Half a mile beyond the fossil locality the beds pass down into the sandy purple beds of the Pangyun group which become more arenaceous as they are followed west.

Very typical pink Naungkangyi mudstones crowded with fossils—brachiopods, cystidean plates, crinoid stems and bryozoan remains, are found on the Mong Hseng-Man Sak road some two miles south-east of the latter village.

Panghsapye Graptolite Bed.

Immediately above the purple sandy shales at the top of the upper Naungkangyi beds, a thin band of carbonaceous shales is found which contains graptolites in large numbers. The horizon is a most persistent and characteristic one and has already been found at the base of the Silurian system in many parts of the North Shan States. It is very liable to erosion on account of its soft character, and its outcrop is very apt to be concealed by rain wash. It was first found in the Bawdwin district by Dr. Maclaren in the Nam Pangyun valley, $1\frac{1}{2}$ miles up from its junction with the Nam Tu, as a black carbonaceous shale containing poorly preserved and fragmentary graptolites of Llandovery age.

I have found the southern extension of the band where it crosses the bed of the Nam Tu, about a mile below its junction with the Nam Pangyun and the main stream, where it is a band of black slate containing abundant specimens of *Monograptus* sp.

Further north in the valley of the Nam La it is again met with, but beyond this it disappears and is probably lost beneath the overlapping Nam Hsim sandstones.

Nam Hsim Sandstones.

These Silurian sandstones form a band running at first north and south and then turning towards the north-north-west. The zone of country occupied by the sandstones is high and well-marked, for they resist weathering much more than the softer formations on either side of them. Streams flowing from west to east to join the Nam Tu, commence in narrow valleys on the hard rocks of the Pangyun series, broaden out on the softer Naungkangyi horizons and then enter enclosed valleys with high rock walls as they cross the Silurian strata.

La Touche's general summary of the rocks of this group is as follows :

A sandy series at least 2,000 feet thick, sometimes very coarse in texture, and elsewhere fine-grained and compact, hard and splintery. Occasionally their boundary with the lower rocks is marked by beds of coarse conglomerate, consisting of waterworn pebbles and boulders of Chaung Magyi quartzites. Where these are absent the lower beds of the sandstone are usually coarse-grained and for some distance up from their base are strongly

felspathic and usually of bluish-grey or purple shades. These gradually become less felspathic, passing into fine-grained brown sandstones, with layers of a hard, white, very fine-grained quartzose sandstone.

The Pangyun valley section in ascending order is hard white sandstones with a high easterly dip followed by softer sandstones with ferruginous patches in miles $10\frac{1}{2}$-11. Below the latter are fine-grained, reddish-purple sandstones in excellent exposures, striking north 30° west, south 30° east and dipping at 58° easterly, yellowish-brown fine-grained sandstones with thick reddish bands, shattered and full of cleavage cracks follow. The reddish sandstones then become more strongly developed and are crossed by two well-marked joint systems perpendicular to the bedding, which split the rock into big tabular masses that have a tendency to peel off and fall down on to the line. These are followed by hard greyish-white quartzitic sandstones again. Similar beds have been found wherever traverses have been made across the band of rocks as mapped.

Another long zone of Nam Hsim sandstones lies between the Chaung Magyis and the Pangyun beds. It is a continuation of a well-known band already found further south which I follow La Touche in regarding as an overlap by the Nam Hsims of the Naungkangyis and Pangyuns, subsequently dislocated by an overthrust or a fold more or less parallel to the Nam Tu. This subject is dealt with more fully in a subsequent paragraph. Felsphatic horizons are commoner in this western band than in the eastern one, and it is often exceedingly difficult to determine where the junction of the Nam Hsims with the Chaung Magyi rocks is on the one hand and with the Pangyun group on the other, especially as the latter often contains horizons very similar in colour and composition to some of the Nam Hsim rock types. I do not claim accuracy for my boundaries of this band as mapped, for a very much longer time ought to be given to it than I could spare. I shall be satisfied if the general extent and direction as delineated is eventually proved correct.

Plateau Limestone.

To the east of the Nam Hsim zone, the Plateau Limestones occupy the whole country except where they are overlain in the south-east of the map by the red beds of the Namyau series of jurassic age. It is unnecessary to give a detailed description of

the great Plateau Limestone series, which is of no importance as far as Bawdwin itself is concerned, so I shall merely make a few general remarks about it, taken mainly from La Touche's writings. It is the most widely prevailing rock of the Northern Shan States and to its peculiar constitution and mode of weathering the distinctive character of most of the Shan plateau is due. This great limestone mass which has a thickness in some exposures of at least 3,000 feet extends considerably beyond the political boundaries of the Northern Shan States, into the Southern States and Lower Burma on the south, and across the frontier into Yunnan on the east. The typical rock is a white or light-grey limestone, which weathers to a dark-grey and is often stained red by iron oxides both on the surface and along the joint planes. It is often hard enough to strike fire with a hammer, and sometimes emits a fetid odour when broken. In texture it is sandy to the touch and has a fine granular appearance, but except near its boundary with the older formations, where it occasionally passes into a sandy limestone, it contains very little silica or argillaceous matter. The Plateau Limestones vary from an almost pure calcite containing over 99 per cent. of that mineral, through dolomitic limestones with from 19 to 33 per cent. of magnesium carbonate, to rocks containing the carbonates of lime and magnesia in the proportions of 55 to 44 per cent. respectively, or practically speaking, pure dolomites.

The limestone bands are exceedingly crushed, indeed it is unusual to find a piece sufficiently large for a hand-specimen which is not seamed in all directions by veins and fissures filled with calcite or dolomite. Recrystallisation of the dolomite is also an almost universal development. Throughout the whole of the continuous expanse of limestone, extending from Maymyo to the Salween, with one notable exception, not a single determinable fossil that could be seen with the naked eye has been discovered. This paucity of organic remains, together with the rarity of outcrops of more than a few square yards in area, the homogeneity of the whole formation and the irregularity of the dislocations that have affected the rocks, make any attempt to follow up definite horizons or to establish any divisions within the formation, a hopeless task, although it bridges over a period of continuous deposition which extended from the close of the Silurian epoch, as shown by the graptolites of the Zebingyi beds, to the Productus and Fusulina limestones of Carboniferous age.

The only locality where the lower Plateau Limestones have yielded fossils is near the village of Padaukpin, some 12 miles east of Maymyo, where a very rich and varied assemblage of fossils has been obtained, which prove that these particular beds are the homotaxial equivalents of the Middle Devonian, or Calceola stage, of Western Europe. Excellent exposures of typical Plateau Limestone occur in the bed of the river at Nam Tu. Here they strike north 20°-25° west—south 20°-25° east and dip easterly at 75°-80°. Interbedded with them below the railway bridge are reddish-brown and hard reddish sandstones; this is an unusual association and is therefore mentioned.

Namyau Beds.

The Namyau series of Jurassic age rests unconformably on the Plateau Limestone. It is distinguished by the dark-red to purplish-red colour of its sandstones, though beds of grey and pepper and salt sandstones and bands of yellow clay are sometimes interstratified in the higher parts of the series. Its thickness must be several thousands of feet, but in no case have continuous sections, good enough for measuring, been found. Bands of hard fine-grained limestones which are often quite argillaceous and fossiliferous occur at the base of the series. The formation covers a considerable area in the Northern Shan States and occupies the greater part of the country through which the Burma Mines Railway runs from Nam Yao to Nam Tu. Limestones of this series are mined near Hsaī-hkao for smelting purposes.

Recent and Sub-Recent.

In addition to the recent alluvium which borders some of the larger streams in the district I have noticed raised river terraces both in the Nam Kung and Nam Pangyun streams, which point to recent uplifts in the region. None of the late Tertiary fresh-water or lacustrime deposits, which attain considerable importance in other parts of the Shan States, occur in the Bawdwin district.

Structure.

The Chaung Magyi highlands in the west formed an old land surface on which the succeeding Palæozoic formations were laid down. The general strike of these is from north to south or north-north-west to south-south-east, with a prevailing easterly dip.

The most important structural feature of the district is the continuation of the great Lilu overthrust, one branch of which runs in a north-north-westerly direction and separates the western band of the Nam Hsim sandstones from the Pangyun beds. It is true that the effects of the great fault are not so marked here as they are further south, and it probably dies out completely a few miles further north where it enters the Chaung Magyi rocks. The other branch of the fault passes close to the eastern boundary of the ore-channel and continues south across the Pangyun and Nam Kung valleys to meet the former south of the Nam Tu-Nam Hsan road. Its exact line has not been definitely mapped but its effects are very evident in the intense crushing and dislocation of the strata. These are particularly evident in the S. gorge, in the E. R. valley, and further south along the road already mentioned. To the north, the Bawdwin branch of the fault seems to pass close to Lao-ka-ya and then to continue north along the valley of the Nam It. "The cause of such a dislocation having taken place along this particular line is perhaps to be found in the existence, only a short distance to the west, of the unyielding mass of the older Chaung Magyi rocks, forming the old land of Taungpeng" (La Touche).

PART II.

ORE BODIES.

The ore bodies at Bawdwin are all confined within a well-marked zone or ore-channel, with the exception of the subsidiary Goldhole ore deposit which seems to lie on another line, but on which sufficient exploratory work has not been done to enable its true relationships to be definitely decided. The main ore-channel is at least 8,000 feet long and is probably 400-500 feet wide. As Maclaren has already pointed out in his manuscript report, the northern limit of the channel ceases at the Goldhole Fault, not because it has heaved it (for the fault was formed prior to ore deposition), but because it threw rhyolite across the track of the fault zone in which the ore was developed. The fault zone certainly continues through the rhyolite as is proved by the veins of quartz and barytes which traverse it, but no ore replacement took place. This was entirely confined to the tuffs. The ore-channel is probably connected with the main line of faulting mentioned earlier, where crushing has been of a most intense description and the shear planes and fissures thus produced have afforded easy passage to the mineralising solutions which have replaced the original country rock, wherever this has been congenial. The ore-channel plunges to the south at a very low angle, passing a short distance below the level of the old Chinese adit level (171 feet below the collar of the vertical shaft at 3,600 feet south of the vertical shaft); it is capped by the Pangyun beds for a part of its extension towards the south, but is exposed at its uppermost limit in the deep S. gorge, to the south of which it certainly disappears beneath the thick covering of the Pangyun Series above it. Along the whole of this 8,000 feet and still further south, as far as the tuffs extend, though this is an unknown distance at present, ore bodies can be reasonably expected. So far as we know, the ancient Chinese miners worked the upper part of the ore-channel at its northern end fairly effectively for some 3,000 feet. Their adits to the south of this are regarded by Maclaren as opening up flat ore floors of small extent which he supposes to occur sporadically in the lower felspathic beds of the Pangyun series.

Within the ore-channel the following lodes have been discovered:

(1) a western lode, the Burman in the vertical shaft section, (perhaps represented further south by the Maingtha

lode) and the Chinaman ore-body in the Amphitheatre section. These two lodes are very different in character; the former being a thin regular vein of lead-silver-zinc ore, and the latter an enormous replacement deposit of zinc-lead-silver ore;

(2) a central lode, the Shan-Palaung which parallels the Burman in the vertical shaft section about 150 feet further east;

(3) an eastern lode, indicated by the workings in the Jail and upper Dormouse ravines.

Only the Burman, Shan, and Chinaman lodes have actually been opened up, the presence of the others is mainly deduced from open-cuts or old workings. Their inter-relations are at present unknown, and will remain so until the Amphitheatre and vertical shaft sections of the mine are joined at deep levels. The most reasonable hypothesis at present is to regard them as members of one system, perhaps continuous lodes, probably separately blocked out by cross faulting. Another theory regards the lodes in the vertical shaft section as originating from the lenticular splitting of the Chinaman ore-body to the north.

The Chinaman ore-body is by far the largest and most important deposit yet discovered at Bawdwin and I shall therefore describe it first. It has been explored by three levels, the zero level, 102-foot level and the 171-foot level, by diamond drill bore-holes and by an internal shaft.

The Zero Level.—The zero level was really made for ventilation purposes in preparation for stoping operations and starts from an adit crosscut tunnel at 1,085 feet south. The drives and crosscuts on this level encountered old filled Chinese stopes. Some copper ores occur in it associated with the zinc blende and galena. The level is a very hot one, the high temperature being due to the oxidation of the sulphides and the decay of the timber sets left by the Chinese. Two rises which are 100 and 128 feet high respectively, go from it to the Amphitheatre passing mainly through old fill.

The 102-foot level.—The 102-foot level, also known as the Drainage tunnel, is largely in Chinese workings, the low-grade ore and old fillings of which are said to average 12 oz. silver, 16·3 per cent. lead and 20 per cent. zinc. But south of crosscut 1,120 feet south there are indications of the development of a zinc-lead core to the ore-body

such as is seen on the 171-foot level below. As the richer ore from this level has been removed by the Chinese the remainder is of lower grade than the general average of the mine. The rises and winzes connecting the 102-foot with the zero level, surface or the lower 171-foot level, as the case may be, pass through old workings of fairly low grade ore.

The 171-foot level or Dead Chinaman Tunnel. The portal of the tunnel is situated at 3,650 feet south and 50 feet west of the vertical shaft. It enters the ore channel at a point 1,887 feet south of the shaft and at a horizon about the same as the 171-foot level at the shaft and is driven right along the strike of the ore-body, nearly to the Ssu-Ch'uan fault, about 450 feet south. From about 1,850 feet south to 600 feet south approximately, a length of 1,250 feet, the tunnel is in ore nearly the whole way. A series of crosscuts from the level on both sides has enabled the width of the ore body to be made out. It possesses a core of high grade zinc-lead ore extending from about 1,730 feet south to 1,100 feet south varying from 10 to 100 feet approximately in thickness. Outside this on the east is a zone of lead-zinc ore extending from 1,830 feet south to 1,100 feet south, and on the west from about 1,400 feet south to 700 feet south. The former has an average width of about 40 feet; the latter is narrower and only averages about 25 feet. Low grade extensions exist on the east from 1,800 feet south to 1,300 feet south, and on the west from 1,500 feet south to 650 feet south.

There is a perfect gradation from one ore to the other and the boundaries are arbitrary ones determined entirely by assay. The following are taken as type assays:—

CLASS OF ORE.	Ag. (oz).	TYPE ASSAY.		
		Pb. Per cent.	Zn. Per cent.	Cu. Per cent.
Zinc-silver-lead ore . .	24	26	30	..
Lead-silver-zinc ore . .	17	24	14	..
Silver-lead-zinc ore . .	40	30	26	..
Copper-silver ore . .	8	..	..	15

The Internal Shaft.—The internal shaft is sunk from the 171-foot level at coordinates 1,505 feet south and 175 feet east. Several crosscuts have been put out which show the average values from zero to 126 feet to be silver 15·8 oz., lead 20 per cent. and zinc 24·6 per cent. The average value of the crosscuts at 67 feet and 124 feet down is, silver 18·4 ozs., lead 21·3 per cent., and zinc 21·0 per cent. over a width of 90 feet. By the end of 1915 the shaft had reached a depth of 446 feet below the Dead Chinaman Tunnel and it is now within about 50 feet of the random of the Tiger Tunnel, which is to be the main avenue of drainage and transport. Large stretches of high grade silver-lead ore have been encountered as well as high-grade zinc ore. When I examined the shaft in May, 1915, it was being sunk through practically pure sulphides. Much of the argentiferous ore assayed from 40 to 50 ozs. of silver and 40 to 50 per cent lead. Main levels leave the shaft at 300 feet and 430 feet.

Between 280 feet and 430 feet the internal shaft was in the foot-wall of the ore body, but I understand it subsequently ran again into ore. Crosscuts from the 300 feet level of the internal shaft have disclosed the presence of rich lead-silver ores on the hanging-wall side.

The dip of the Chinaman ore-body is about 70° in an approximately westerly direction but the high silver-lead bodies are nearly vertical. They will be found to be offshoots from the main mass. Although the richest part of the Chinaman ore-body underlies the lower portion of the Amphitheatre, any outcrop of the great lode was removed long ago by the ancient Chinese. It is difficult to gauge where its outcrop was without knowing its underground position, indeed the early European development at Bawdwin would have been very different if the size and extent of the body could have been recognised at the surface. The kaolinised tuffs of the Amphitheatre with their stringers of malachite, azurite and oxidised lead minerals are all that is left. Further south there is no indication at all on the steep hillside.

The Chinaman ore-body is a great replacement deposit which occurs on the hanging-wall side of the ore channel. The axis of the thickest part of the sulphide core strikes approximately 25° west of north and has a dip of 70°-80° to the west. At the time of my inspection it had been proved to a depth of 259 feet below the

level of the Dead Chinaman Tunnel but later it has been found much deeper.

The hanging-wall seems to be more or less regular, though from the nature of the deposit a certain amount of mineral may be expected beyond it. The foot-wall is ill-defined, and there is a gradual passage from the solid mixed sulphides of lead and zinc through a second-grade ore composed of dark grey tuffs infiltrated with silica and containing nests and strings of sulphides, in which the metallic sulphides gradually become poorer, until unaltered rhyolite tuff, and in some cases true rhyolite, is found. At the surface kaolin is a common mineral in the country rock, but it becomes less with depth, whereas chlorite and sericite become commoner. The deepest Chinese workings are bottomed at about 40 feet below the level of the Dead Chinaman Tunnel.

The ore-channel itself is a nearly vertical zone of combined faulting and shearing and although the ore-body is largely a replacement deposit, I am not prepared to state that certain parts of its central core might not have been formed by the filling of open spaces. The smaller veins described below the Burman, Shan, Palaung and others—seem to occupy fault fissures though this is not proven as yet.

The Chinaman ore-body has certainly been cut by fissures since the formation of the greater part of the ore. Along such lines of disturbance the mixed sulphide ore has become schistose and slickensided, or, again, crushed and recrystallized as in the massive variety called steel ore. Although it is dangerous to generalize from one section, it appears from the work done in the internal shaft that the ore is becoming richer in zinc blende with depth. Pyrite too seems to be increasingly abundant though merely as a negligible accessory mineral.

The oxidised ores, anglesite and cerussite, are now of no commercial importance, though it is possible they may have been so in the upper zone which was worked by the Chinese. Both minerals, and pyromorphite, occur in small quantities well within the sulphide zone in the Dead Chinaman Tunnel but in vugs or as implanted crystals on the sulphide ore, or, again, filling small fissures and cracks in it, as if they had been carried down from the zone of oxidation and deposited there. I have not seen a single instance of the sulphide ore in process of oxidation. Calamine only occurs at the surface

and then in the smallest possible quantities. The Burman and Shan lodes are confined to the vertical shaft section, and as operations in this part of the mine had been temporarily abandoned during my visit and the workings were standing full of water, I have no personal observations to make on the lodes, and my remarks are confined to information supplied by officials of the Company. They are two parallel ore-bodies which have been explored to a depth of 430 feet below the collar of the vertical shaft.

The Burman lode is thin but persistent in depth so far. It crops out near the Ssu-Ch'uan fault as a series of small parallel stringers of ore. The country around it and the Shan lode is badly faulted and its true direction is not easy to follow in the present stage of development.

On the 102-foot level this lode was intersected by no. 1 crosscut 50 feet from the shaft, it had improved both in width of stringers and quartz and the 9-inch vein assayed 15·55 per cent. lead, 9 oz. silver, 27·85 per cent. zinc. A drive for 18 feet on this showed the vein to increase to 54 inches and to assay 20·41 per cent. lead, 12·10 oz. silver, and 25·03 per cent. zinc. On the 171-foot level it was met with 25 feet from the vertical shaft and proved to be about 2 feet thick averaging 37·8 per cent. lead, 26 oz. silver, and 18·5 per cent. zinc. On the no. 3 north-west drive the face at 59 feet assayed 29 per cent. lead, 9 oz. silver and 13 per cent. zinc over a width of 31 inches. In the no. 1 south-east drive from 132 feet to 155 feet it was 33 inches thick and averaged 29 per cent. lead, 11 oz. silver and 21 per cent. zinc.

On the 300-foot level the Burman lode over a length of 190 feet shows an average width of 31 inches of lead-zinc ore assaying 33 per cent. lead, 37 ozs. silver, 16 per cent. zinc, and a trace of copper. The vertical shaft cuts the lode at 110 feet but no crosscut has been run to cut it on the 430 foot level. It will thus be seen that the lode averages about 2-foot thick and is high in lead and silver but low in zinc.

The Shan lode is parallel to the Burman and some 150 feet, approximately, further east.

The 102-foot level encountered old Chinese workings, but pillars and parts of the vein left by them were found and assayed. Thus in the main east crosscut at 198 feet, it was 60 inches thick and assayed 34·3 per cent. lead, 22·5 ozs. silver and 21·2 per cent. zinc.

On the 171-foot level the main east crosscut intersected the lode 170 feet east of the shaft. It was here 2 feet wide assaying 13 per cent. lead, 27 ozs. silver, 29 per cent. zinc and a trace of copper. At the 300-foot level it was intersected in the main east crosscut at 194 feet from the vertical shaft when it appeared to be 9 feet wide but very faulted and containing much water. A sample across the first 4 feet assayed 14 per cent. copper, 21 ozs. silver, 1 per cent. lead and 1·3 per cent. zinc. Two truck samples of 40 tons gave 8 per cent. copper, 6 ozs. silver, 9 per cent. lead, 1·2 per cent. zinc. To the south of the crosscut a much larger copper ore body was discovered varying in width from 4 to 17 feet and averaging 7·8 ozs. silver and 15·4 per cent. copper.

On the 430-foot level the main east crosscut at 124 feet cut 3 feet of ore assaying 4 ozs. silver and 6·8 per cent. copper, and at 155 feet intersected the Shan lode which for 9 feet assayed 23 ozs. silver, 30 per cent. lead, 20 per cent. zinc and 0·9 per cent. copper. The country is disturbed by faulting and the next 10 feet on the south side of the crosscut assayed 18 ozs. silver, 25 per cent. lead, 14 per cent. zinc and 9 per cent. copper.

The Shan lode therefore, like the Burman, is a small one but has been proved to a depth of 438 feet below the collar of the vertical shaft. The development of chalcopyrite on the 300-foot level which again becomes low again on the 430-foot level is remarkable.

The Palaung lode was first worked as an open-cut between the Jail and Dormouse ravines. In 1909 an attempt was made to crosscut its continuation by means of a winze sunk from the Sulphide Tunnel, but old Chinese drives which were full of water were encountered and caused much trouble. What was probably the continuation of this lode in depth was met with in east crosscut 800 feet south on the Drainage Tunnel at the 102-foot level. It was first encountered at 254 feet in and was only 2 feet wide but carried good copper and silver values. It was driven on for 28 feet and samples over a width of 27 inches gave silver 15 ozs., copper 2·7 per cent., lead 9·7 per cent. and zinc 11·4 per cent.

The Dormouse lode was first noticed in the Dormouse Ravine. Its probable continuation in depth was encountered in the same crosscut from the Drainage Tunnel as the one which displayed the Palaung lode described above. At 327 feet a thickness of over 5 feet of ore was passed through from which two samples assayed silver 9·3 ozs., lead 7·5 per cent. and zinc 37 per cent.

The name *Kachin lode* has been given to a small copper vein which has only been seen in the vertical shaft section.

It is impossible to make any general observations on these lodes at present as so little work has been done on them. It seems to me probable that they are branches of the Chinaman ore-body and were at one time continuous but have now been separated into blocks by cross faulting which has been frequent and complicated at Bawdwin. In comparison with the great Chinaman lode they are insignificant, though some may prove of value for their copper and silver-lead contents. The possibilities of the ore channel in the vertical shaft section are by no means exhausted and a great deal of exploration work, especially towards the north, is necessary before it can be stated that no other lodes exist.

The Goldhole ore-body.—This is an independent ore-body which does not appear to belong to the Bawdwin ore-channel series. It lies 2,000 feet north of the vertical shaft and the ore from it was used at one time as a flux in smelting the Chinese slags. It seems to be a thin, flat-bedded, pyrite deposit containing some chalcopyrite and small quantities of chalcocite. It probably strikes north-north-west and south-south-east and dips at a low angle to the west. Near the surface it is changed to a ferruginous gossan which has been proved to contain small quantities of gold and native silver. The deposit seems to have been formed near the junction of two faults, but I was unable to establish its exact relation to them in the absence of extensive workings. It has been opened up by a drainage adit, but, until the north drive of this has been continued through and beyond the ore, I cannot say more about it. A series of winzes from the adit would reach the ore at shallow depths and its exploration should not be a difficult matter. That the deposit contains copper is confirmed by the thick growths of copper sulphate crystals on the adit walls and roof, and by the replacement of the rails by copper since the level was abandoned.

Faults.

The faults may be divided into two groups, those prior to ore deposition and those which took place afterwards. Maclaren regards the ore-channel as bounded by two main faults which are approximately parallel and 500 feet apart. The north-easterly member forming the boundary between the rhyolites and his felspathic grit series (the tuffs of the present classification), being termed the Boundary

Fault and its apparent dip being south-west at about 80°. He regards the evidence for the existence of this fault as fairly clear, a conclusion with which I agree. Arguing from the discordant dips of the thin-bedded Pangyun beds he assumes that the ore-channel is bounded on the west by another called the Central Fault, but I am more inclined to agree with his alternative assumption, that the zone in which ore deposition has taken place has been the scene of several parallel, though not necessarily continuous movements, developed by one long-continued uplift along the main line of weakness. This has resulted in a shattering of the rocks, thus rendering them permeable to the ore-bearing solutions from below, and the deposition of their load along the main planes of movement when these happened to lie in the rhyolitic tuffs. In other places no impregnation of minerals has taken place and the faulted zone is barren. The main zone passes to the south through the S. gorge west of Tiger Tunnel.

Maclaren has also pointed out that the Goldhole Fault which marks the northern limit of the ore channel is prior to ore deposition and has apparently thrown the country to the north of it some 500 feet to the south-west. Another well-marked fault appears to branch off from the first where the latter crosses the Dormouse ravine, its path across the Jail, upper Jail, Bazaar and Goldhole ravines being marked by vein quartz, and it eventually becomes the boundary fault of the Goldhole deposit on the west.

The great Bawdwin overthrust has already been described.

But in addition to these big faults, which have been instrumental in causing the mineralisation of the tuffs, there are a large number of others later in origin than the ore-bodies, which they often displace. Maclaren has pointed out that the data available at the time of his visit was far too scanty to permit of any generalisations of real value, since some faults, striking enough in the country rock, may yet exercise an inappreciable effect on the lodes, and so far it is unfortunately only in the country rock that they can be seen. I was confronted with the same difficulty, for underground operations had not reached a sufficiently advanced stage for the main faults to be properly plotted out and their effect on the different lodes calculated. There is a notable absence of thin, well-defined beds which could be used as fault registers.

A diagram prepared from the mine plans is appended (Pl. 4) showing the faulting at present revealed on the 171-foot level.

From this it will be seen that omitting the Taungpeng boundary fault, the main dislocations fall into two groups, the first comprising the Yunnan and Ssu-ch'uan faults dipping towards each other the first at 74° and the second at 75°. Their effect on the ore-body is unknown. Some of the smaller parallel faults have shifted the ore-body, or portions of it, a few feet. The other group is represented by the Hsenwi fault, itself offset by certain minor dislocations. It has cut off the southern end of the Chinaman ore-body. Minor faults are of most frequent occurrence and are especially well exhibited on the right of the diagram, where they are plotted from their occurrence in crosscut 2,950 feet east. The question may be asked what has become of the faulted portion of the great lode to the south. A long drive along the channel on the 171 feet to 3,700 feet south failed to reveal any traces of it, as also did crosscut 2,950 feet east. Until more is known of the movements brought about by the Hsenwi fault it is impossible to prophesy anything. I would recommend a deeper drive more to the south-east and a long crosscut out to the east, both below the base of the sediments.

Underground in the tuffs, the fault planes are usually full of gouge—a kind of clay resulting from their decomposition - and they therefore make dangerous ground when crossed. Consequently at these places the levels are always close-timbered and it is impossible to examine the fault planes.

Of the numerous faults seen underground and on the surface at Bawdwin, so far only the Ssu-ch'uan has been identified in both cases. It forms a narrow fissure bounded by steep walls near the vertical shaft, but the exact thickness of the gap is difficult to measure owing to the gouge and débris which fills it.

Mineralogy of the Ore Deposits.

Only those minerals are described which are of interest in connection with the ore deposits.

Silver.- Native silver in its characteristic moss-like aggregates and plates has been reported from the Goldhole gossan.

Copper.– On the waste heaps of the Goldhole adit I found native copper in thin films and dendritic growths associated with a brecciated white quartz. Occasionally the quartz is held together by the copper which has been deposited in the network of irregular cracks which traverse it. The metal is either dark and tarnished or else stained blue from its own basic hydration products,

Dendritic native copper has also been found at the edge of the Chinaman ore-body in the zero level (south drive 207 feet east at 1,500 feet south), in association with a very kaolinized tuff.

Galena.—The isometric sulphide of lead is with the exception of zinc blende, the most important mineral of the Bawdwin area. The long series of assays now available show that it carries all the silver present in the mixed ore which is highly argentiferous. Only very rarely is the mineral found in large distinct crystals, its commonest occurrence being a massive, compact aggregate, the grains ranging in size from one or two mm. in diameter—when the fresh fracture has a glittering appearance due to its brilliant cubical cleavage planes—to the minute variety with the dull appearance of steel galena. There is practically no gangue associated with the high-grade lead-zinc ore of the Chinaman lode. In the lower-grade ores the sulphide occurs as irregular grains disseminated through kaolinized and sericitized tuffs.

The galena is invariably associated with zinc blende, usually on a cryptocrystalline scale; sometimes, however, the blende tends to segregate in small patches or strings, or in well-defined bands forming a typical ribbon-ore. Chalcopyrite and pyrite also occur as grains disseminated through the lead and zinc sulphides. The rich ore very often exhibits cleavage, slipping planes, banding, schistosity and curved cleavage of the individual grains, conditions probably due to pressure. The galena oxidises to cerussite and anglesite. Pyromorphite occurs in small quantities also.

Chalcocite.—Copper glance, or cuprous sulphide, has been found associated with covellite, both in the Goldhole level and in the upper parts of the Chinaman lode.

Covellite.—Cupric sulphide forms a thin film of flexible plates of a dark indigo-blue colour on pieces of zinc ore from the ancient workings of the Chinaman lode. Both chalcocite and covellite were first recognised by Mr. H. C. Jones, Curator of the Geological Survey of India, on specimens submitted to him for examination. They both occur in minute quantities and are of no economic importance. The films of black sooty material found on lumps of ore worked by the Chinese are of a deep indigo-blue colour when freshly exposed and are probably covellite.

Melaconite.—Cupric oxide, CuO. A black pulverulent mineral from the face of the Goldhole working has proved on examination to be melaconite.

Zinc Blende.—This is always associated with the galena, and often with small amounts of pyrite and chalcopyrite. In the ribbon-ore it occurs in thin regular bands of a brownish-black colour. As a rule, however, it is found in minute scattered patches, stringers or thin films, or, commoner still, on a practically cryptocrystalline scale hardly recognisable until sections of the ore are examined under the microscope, when it is at once distinguished by its semi-transparent brown colour. At the bottom of the internal shaft in April 1915, a massive fine-grained zinc blende with a pitchy lustre was met with. Pieces of resin blende of light brown colour were picked up on the vertical shaft dumps; they showed numerous minute cracks filled with pyrite.

Calamine.—Small quantities of the carbonate of zinc have been detected with other oxidation products in the upper levels at Bawdwin.

Chalcopyrite.—Copper pyrites is distributed sparingly through much of the high-grade ore and occurs in some quantity, in the Shan lode, in the massive condition often associated with calcite.

Pyrites.—Iron disulphide FeS_2 is common in small grains throughout the Chinaman ore-body and abundant towards its peripheries, and also filling cracks and hollows left by solution. Occasionally it forms bunches, especially in the Goldhole.

Malachite.—The green carbonate of copper is noticed in small quantities in the surface rocks of the ore-channel. It usually occurs in thin lamellæ along the shear planes of the country rock and is of no economic importance. It is especially common in the neighbourhood of the Dormouse Ravine and the Amphitheatre. It is invariably associated with azurite.

Azurite.—The blue copper carbonate is found as thin films impregnating the decomposed rhyolitic tuffs and also in small groups of tabular crystals. Both carbonates are produced by the oxidation of chalcopyrite.

Anglesite. Lead Sulphate.—This is a common mineral in the zone of oxidation, though both anglesite and cerussite are found as crystals implanted on unaltered sulphide ore by solutions percolating down from the zone of oxidation. The usual form assumed by anglesite crystals is that of a simple orthorhombic prism, elongated somewhat along the vertical axis, and generally terminated by pyramidal faces. Many of the crystals are by no means so simple as this, the pyramidal faces being especially liable to a variety

of combinations which cannot be deciphered without crystallographic measurement. Tabular crystals, formed by growth parallel to the *c* axis, are of rare occurrence whilst a massive variety is sometimes found in small quantity as a coating on galena. As usually found, the crystals are coated with a thin opaque film of a white substance, which is at once removed by dilute acid and may consist of lead carbonate. All the specimens collected are quite colourless, and are often transparent, whilst their brittleness is especially noticeable; generally they possess an adamantine lustre, but crystals with a duller and more vitreous lustre have been noticed. Anglesite was probably mined by the Chinese; it is certainly of economic importance at Bawdwin to-day.

Cerussite.—The carbonate of lead is found in association with anglesite and sometimes with malachite and azurite and was one of the oxidised ores, though it does not now attain commercial importance. I have seen a few massive specimens made up of lustrous white crystals, but it is common in crevices and cavities in the sulphide zone forming tabular penetiation twins or, again, in minute fragile sparkling druses. The twins are often tinged blue or green by copper carbonates.

Massicot.—Lead monoxide occurs as an impure earthy yellow powder in the oxidised zone in small quantities.

Pyromorphite.—The phosphate and chloride of lead occurs with anglesite on galena in the Dead Chinaman Tunnel as small prismatic crystals of a fawn colour which show a slight tendency to become barrel-shaped or to taper down to a point.

Erythrite, or cobalt bloom, occurs as a pinkish-red incrustation on certain varieties of the massive sulphide ore. It is probably produced by the decomposition of small amounts of cobaltite.

Goslarite.—Zinc sulphate forms white crystals and incrustations on the walls of the upper levels in the Chinaman lode.

Brochantite.—Basic copper sulphate forms blue crystals and incrustations in similar situations.

Barytes.—Barium sulphate. Though not actually associated with the ore bodies themselves this mineral is abundant in veins in the immediate neighbourhood of Bawdwin. It occurs in massive coarse-grained aggregates, which are often full of small cavities. The broken surfaces of some of these show a platy structure with curved surfaces and a vitreous lustre. It is found on the lip of

the Amphitheatre and in large masses in that great excavation, which was originally an open-cut working but has been enlarged by landslips. A barytes vein also crops out at the head of the E. R. valley.

The Ores.

The essential constituents of the Bawdwin ores, with the exception of the copper ores of the Shan lode, are galena and zinc blende, intimately intergrown and of a fine to medium grain. The sulphides, pyrite and chalcopyrite, are sparingly distributed through the zinc-lead ore, the latter being for the most part exceptional in the great mass of the ore rather than characteristic, though there is sometimes a concentration of this mineral on the hanging-wall side of the ore-body. For example it occurs on the third level of the winze in this position, the winze itself being 300 feet north of the internal shaft. The galena-zinc blende ore is always argentiferous and the richer the mixture is in galena, the higher does the silver content rise. A summation of the assays of the crude high grade sulphide ore of the 171 feet level shows 19·2 ozs. of silver to the ton of ore, 24 per cent. of lead and 20·7 per cent zinc.

The high-grade ore is pure enough to be selectively won, handpicked and shipped. The lower grades consisting of galena and zinc blende mixed with gangue will have to be crushed and concentrated locally to fit them for the market, which will add an increased charge to the working costs but decrease those due to transportation. The high-grade copper ores of the Shan lode can be handpicked and shipped or else smelted locally.

The gangue of the Chinaman ore-body consists of the metamorphosed country rock and a little quartz. Every gradation can be found from pure mixed sulphides to tuffs which show no signs of mineralisation. In the second-grade ores the galena is seen metasomatically replacing the altered felspars of the rock or even its groundmass, while both it and the blende form numerous ramifying veinlets crossing the rock in all directions and leaving little except the original irregular grains of quartz, which in the massive ore are replaced too. There can be no question that the greater part of the galena is of metasomatic origin, for the veinlets possess no regular fissure walls when seen under the microscope but are irregular in width, branching and reticulating in all directions. It would appear therefore that the metallic sulphides

attacked first of all the altered felspars of the tuffs and replaced them. As the process went on, the mosaic-like groundmass gave way to the impregnating solutions and finally the quartz grains themselves were partially or entirely replaced. Specimens can be found showing every stage of these operations. In the early period the outlines of the decomposed felspar crystals are often beautifully bordered with a thin zone of galena. This in turn grades into country rock, containing thin irregular veinlets, nests and finely disseminated patches or crystals of galena, then comes the material composed of the sulphides and residual quartz, and finally, the rich ore itself.

It remains now to discuss those chemical changes which have taken place in the country rock itself both before and after its mineralisation. The clue to these is given by the general silicification of both rhyolites and tuffs, by the abundance of kaolin at the surface and higher levels, and by the presence of chlorite and sericite in the tuffs. Kaolin becomes less in depth, the other two minerals become commoner. The rhyolites and tuffs have both undergone general silicification, consisting in the case of the groundmass, of that peculiar breaking up into irregular areas, alternately light and dark under crossed nicols, which is known as a "quartz mosaic," and in the case of the quartz phenocrysts in the development of a closed area or aureole of quartz which is in optical continuity with that of the phenocryst and extinguishes simultaneously with it under crossed nicols. Along with this silicification there seems to have been some development of sericite at the expense of the felspars. The wide-spread occurrence of chlorite in the tuffs, especially at the deeper horizons, accompanied as it is with the formation of small quantities of carbonates and sericite, appears to me to point to an alteration of the propylitic type, but exactly how these two series of changes are related, or whether the former was confined to any particular series of the rocks and the latter to another, is a matter impossible to decide in the present stage of knowledge. Another point which requires working out in the future when more material is available for study is the formation of the secondary felspar--probably adularia, that water-clear mineral which Maclaren believes to have been formed at the expense of the old decomposed felspar and *pari passu* with which he regards the deposition of chalcopyrite, blende and galena to have taken place in the order named. The kaoli-

nised masses which are found in the country rock of the channel as a lode is approached are supposed by Maclaren to be the decomposed remains of the secondary felspar crystals. The whole series of these changes requires much more study than I have been able to give to them.

But, in addition to the silicification and propylitisation which have taken place there is a later series of changes, the presence of which I regard as perfectly established. I refer to the action of oxidation on the mineralised rocks by reason of their exposure to the atmosphere at the surface. This has certainly resulted in the generation of sulphuric acid from the sulphides. At Bawdwin the honeycombing of the upper parts of the ore channel for some hundreds of years by a perfect labyrinth of Chinese levels, cross-cuts, winzes, rises and stopes, and the slow decomposition of the timber introduced into them by the ancient miners, have not been without a potent effect in this direction. This can be seen in the zero level in which the walls and roof are coated with thick growths of the sulphates of copper and zinc, and the heat produced by the oxidation of the sulphides in the old fill is well-nigh unbearable. As Lindgren has pointed out, the sulphuric acid descends with the surface water and converts the sericitized rocks into kaolin mixed with other oxidation products. Descending still further these sulphuric acid solutions may lose their oxygen, and secondary sulphides with sericite may again develop.

The intimate association of carbonates with the chalcopyrite of the Shan lode is another matter which requires investigation as soon as the underground workings can be examined again. It seems to me, from my examination of a few sections of ore from the lode, that here the replacement may have taken place in two steps. The calcite has first replaced the tuff, or part of it, and then the chalcopyrite has attached the carbonate.

Sometimes I have found small pieces of rather coarse galena embedded in quartz, the crystalline structure of which was very well developed. Although it must be very closely associated with the replacement ore, this material is clearly secondary and has been deposite din narrow open fissures in the main ore-body. The steel ore has been produced by crushing and recrystallization of the sulphides by recent movements since the deposition of the ore. That these movements have occurred is proved by occasional slickensiding of the rich ore.

Order of deposition of the sulphides.

In my earlier report on the Bawdwin Mines I wrote, "the microscopic examination of various specimens shows that iron and copper sulphides when present with the others were the first to be formed, for they have been found in grains surrounded by galena, the converse arrangement not having been observed. In the case of the lead and zinc sulphides, the relationships are somewhat ambiguous. Galena has been found surrounded by, and also surrounding, zinc blende. The latter is by far the commoner case, and it may be assumed that as a general rule the zinc blende was deposited prior to the lead sulphide. In most of the sections which were examined the two sulphides of lead and zinc occur in small grains scattered indiscriminately through the rock. It is remarkable, however, that in some instances the sulphides are seen to be growing more or less separately, giving the ore a banded appearance under the microscope." These were incomplete observations based on outcrop material or pieces of ore from the Chinese slag dumps. Later research on the Chinaman ore-body *in situ* has forced me to slightly different conclusions, but even yet it cannot be confidently asserted that the various minerals have always been deposited in the same way in different places, or that the replacement by one particular sulphide went on for a certain period over a large area and was then followed by the deposition of another. Important as the study of the paragenesis of the minerals is, too much reliance must not be placed upon it as a record of a succession of simple events. The time element must be taken into consideration, the repeated movements of the rocks themselves resulting in new fissuring after the partial formation of the ores, and the action of both ascending and descending solutions after their formation in the matter of recrystallization, and chemical changes must not be forgotten. The question is further complicated by the absence of banded deposits in which layers of minerals were successively deposited one on top of another. Investigation is confined to the microscopic examination of thin sections of the massive ores. With these reservations, I now believe that the general order of deposition commencing from the earliest formed was: zinc blende, copper and iron sulphides, and then galena. But the zinc blende at Bawdwin, although it seems to have been the first mineral formed, is restricted to a much narrower area than the galena, which is found far out into the

walls on each side of the ore-body. Indeed it is not unusual to find specimens of the tuffs and even of the rhyolites in the vicinity of the ore-channel which contain no metallic sulphides visible to the naked eye, but which, when examined in thin section under the microscope show their altered felspars (now consisting of kaolin, sericite and secondary quartz) beautifully outlined with a thin line of the lead sulphide. But slides of the rich ore always show the galena traversing the blende. To explain this I assume that the first mineralisation by ascending waters from below consisted almost entirely of zinc blende, which rose along the earlier fault fractures and replaced the rocks on either side, so forming the greater part of the core of the present ore-body. Then followed that widespread breaking-up of the strata, which is exhibited in the S. gorge, and at the head of the E. R. valley, with the result that a much greater area of material was rendered permeable for replacement, by solutions containing the lead sulphide, which then took place. The common occurrence of pyrite in vugs and as implanted crystals on the deeper ore, is either due to a re-deposition of that mineral by descending solutions, or, to a later generation of it by ascending ones. When either it or chalcopyrite appear associated within the mixed sulphides, they seem to have been the second mineral produced, though this is not quite proved.

Origin of the ores.

The general conditions at Bawdwin, both in the ore-channel and surrounding area, point to the fact that the ores are deposits from hot ascending solutions probably under pressure rising from considerable depths. We have seen that the ores were deposited in a faulted zone, which rendered the tuffs themselves permeable to the mineralising solutions. What was the origin of the latter? In seeking for an explanation of this question I have derived much help from the hypothesis advanced to account for the source of the ores of the Coeur d'Alene district in Idaho by F. L. Ransome. In some ways there is a distinct parallel between the two areas though of course on a much smaller scale in the case of Bawdwin. The prevailing country rock in the American field is a fine-grained sericitic quartzite of Pre-Cambrian age and, though traversed by numerous faults of large displacement, the mineral veins follow subordinate fractures of no great throw. The ore deposits are composite veins or lodes, often of considerable thickness formed

partly by filling but largely by replacement along shear planes in sericitic quartzite. The ore-shoots are large, but irregular, and the shear zones are nearly vertical; galena, with some pyrite and zinc blende and in places a little argentite, are the principal ore minerals. At the Bunker Hill and Sullivan the ore bodies do not follow the main wall, which dips 38° south-south-west, but lie in the shattered country within 250 feet above it. Two masses of monzonite intrude the series but at first sight appear inadequate to account in any way for its ore deposits, some of which are 8 miles from the nearest small exposure of intrusive rock. By assuming that these intrusions connect and widen below the surface with an underlying batholith, Ransome shows that there is a sufficiently large magmatic source to give rise to the wide-spread mineralisation characteristic of the district.[1]

I cannot believe that the Bawdwin ore deposits are unassociated with the presence of igneous rock, neither do I think it possible that the ores emanated from the same source as the rhyolites themselves in Pre-Cambrian or early Cambrian times. This has led me to suppose that they are connected in some way with the Tawnpeng granite.

This granite mass occupies the greater part of Northern Tawnpeng. Previously it was only known a few miles beyond latitude 23° but I have now traced its extension up to latitude 23° 15′ and I am certain it continues much further north still. At the same time its eastern boundary with the Chaung Magyi system, previously known as far east as longitude 97° 8′, is now to be placed at 97° 17′ where it is heading still further east in unsurveyed tracts. On the west and north therefore, the Bawdwin area appears to be surrounded by the granite, though a broad zone of rocks belonging to the Pangyuns, Nam Hsims and Chaung Magyis intervenes between them. The nearest exposure of the granite from Bawdwin is 5 miles away, that is to the edge of the great tongue of granite protruding from the main mass and occupying the Loi Maraw area and the valley of the Nam Leng.

The granite is intrusive but so far it has only been found penetrating the rocks of the Chaung Magyi system; but I think that,

[1] Ransome and Calkins:
"The Geology and Ore Deposits of the Coeur d'Alene district, Idaho." *U.S.G.S., Prof Paper*, 62. 1908.
See also Lindgren: Mineral Deposits, pp. 559-562

when the country to the north of Bawdwin and west of Moho Chang is examined, it will probably be found intrusive into much later rocks than these. It is an ordinary granite, consisting of quartz, orthoclase sometimes microcline, and biotite, and occasionally a little tourmaline. It is itself intruded by numerous dykes of diorite and olivine gabbro. Now, considering the great expanse of country which the granite has lately been proved to occupy, it is probable, as in the case of the Coeur d'Alene monzonite, that the exposures are the upper parts of masses which become greater with depth, so that the erosion of a few hundred feet more of overlying rock would probably expose the granite over a much greater superficial area and perhaps reveal it underlying, or in contact with, the Rhyolitic Series at Bawdwin. It is from this underlying granitic magma I believe the mineralising solutions to have emanated, for no other hypothesis accounting for the ores seems tenable. Unfortunately we have no means of determining the age of the granite intrusion at present. La Touche writes that it may perhaps belong to the same period as that in which the ejection of the rhyolites took place, but this is entirely an open question until geological surveys have been carried further north, and I am not inclined to accept it as matters stand at present. The granite is often crushed and faulted, but this may well have been caused by the late Himalayan movements in which the region has participated and which indeed seem to be continuing up to the present time.

As a working hypothesis therefore, I conclude that the ore bodies at Bawdwin were formed by hot solutions from an underlying granitic magma, rising along shattered fault planes previously produced, and replacing congenial rocks, such as the rhyolitic tuffs, whenever they happened to lie in their lines of circulation. They were probably formed under considerable thicknesses of sedimentary strata which have since been eroded away—for it is a region of intense denudation—and they have been crushed and faulted in movements which have taken place since their formation.

ANCIENT AND PRESENT WORKINGS.

The deep valley of the Nam Pangyun afforded the Chinese miners of earlier times a ready means of prospecting the ore-channel which for more than 3,000 feet is penetrated by a maze of ancient workings. North of the vertical shaft there are few workings

on the main channel, the Bat Tunnel being the last prospecting drive in this direction. Old workings also exist on the Goldhole ore body. On the hanging-wall side, the Bridge and other workings show that prospecting was done in this direction too, with what success is not known. Most of the workings are concentrated on the upper part of the thickest portion of the Chinaman ore-body which was reached by adits and inclined shafts from the Nam Pangyun valley, and by roughly spiral incline shafts passing through the overlying Pangyun beds to the ore-channel beneath, from the E. R. valley direction. One of the more important Chinese undertakings was the driving of the present Dead Chinaman adit, which is now the main entrance into the mine, 171 feet below the collar of the vertical shaft. This adit followed an excellent grade until it reached the ore channel, when drifts were made mainly to the north, but also to the south. Some of the Chinese workings have been found in the ore-body 70 feet below the level of the tunnel, and these must have been drained by bamboo pumps which are still in operation in the mines of Yunnan to-day. By means of short lifts the water would be raised to the level of the Dead Chinaman Tunnel whence it would flow out to the surface along the gradient of the tunnel. Underground communications existed between the main valley and the E. R. valley, one of which went by way of the old Chinese incline and through the Red Tunnel. Another perhaps came out into the Stern Valley by way of the Quartz Tunnel. No ore was smelted in the E. R. valley, the concentrates being brought through into the other one by these connections. The whole of the upper portion of the Chinaman lode is honeycombed with drives and crosscuts through which the Chinese burrowed in search of the highly argentiferous lead ore. No great amount of timbering seems to have been used, the more important roads of the mine being arched at the top and of an oval shape in bad ground. Where timbering was necessary as in some of the zero level stopes, bamboo seems to have been employed. Old windlass barrels tapering at either end have been found in some of the reopened workings, and skeletons have come to light pointing to the fatal accident of former days. These skeletons are often manacled, which proves that the Chinese used slave or convict labour, or perhaps prisoners of war taken from the surrounding tribes, who appear to have carried on an intermittent warfare with the invaders. The main workings varied

in height from 3 to 5 or even 6 feet, and are usually well proportioned. At times they expand into irregular cavities where large bodies of the ore which was sought were probably stoped out. Taken on the whole, the old Chinese workings show an admirable degree of mining skill, though this is not surprising to one who has had the opportunity of inspecting native mining methods in China of to-day. At the same time one is impressed by the Chinese system at Bawdwin for it reveals a surprising knowledge of the character, extent and condition of the ore-channel and of the occurrence of the lodes in it. For these reasons, it is vitally important for the modern engineer to explore and survey as many of these old workings as may be made accessible. I agree entirely with Maclaren when he writes "many are only blocked by local falls and I am convinced that reopening and examining these whenever possible will prove not only the cheapest method of prospecting the upper levels but will save duplication of winzes, drives and crosscuts in the examination of the ore-channel."

Workings of present Company.—At the time of my visit, the workings of the present Company, which are shown on the attached plans, consisted of a vertical shaft 437 feet deep, near the north end of the ore belt. From this the following levels took off. A drainage level at 102 feet which extended to 1,827 feet south where it reaches the surface and levels at 171 feet, 300 feet and 430 feet with numerous crosscuts, winzes and rises.

The southern section has a short zero and 102 feet levels both of which are driven mainly in old Chinese workings, but it is really opened up by the 171-foot level. The 171-foot level of the vertical shaft corresponds to the adit level, Dead Chinaman Tunnel, the portal of which is situated at 3,650 feet south and which runs 800 feet in a north-east direction before it turns north along the ore-channel, in which it has been driven some 1,250 feet. An internal shaft was being sunk from this level at co-ordinates 1,505 feet south and 175 feet east, which at the time of my visit had reached a depth of 430 feet. From it drives corresponding to the 300 feet and 430 feet levels of the vertical shaft were to be made. This shaft is to be continued to a depth of some 500 feet below the Dead Chinaman Tunnel, or 660 feet below the collar of the vertical shaft, to meet the Tiger Tunnel which will form the complete working avenue to the mine. Its portal lies on the Nam Pangyun at Tiger Camp, which is on the railway between Bawdwin

and Nam Tu and has an elevation of some 2,500 feet above sea level. The tunnel will be 6,000 feet long to the ore-channel, entering it a short distance south of the Internal Shaft. It was 2,921 feet from the portal at the end of October 1915.[1]

From the great tonnage of proven ore and ore reasonably assured, it is now possible to state that Bawdwin bids fair to become one of the big zinc-lead mines of the world. The persistence of the ore-bodies to great depths depends, in my opinion, on the depth to which the tuffs themselves extend, a question on which there is no information at present, and I consider the southern extension of the ore-channel well worth further underground exploration. Careful and systematic prospecting of the districts north and north-east of Bawdwin is desirable. Eight years ago Mr. La Touche and I strongly advocated underground exploration at Bawdwin, which at that time was merely worked for surface slags. It is a matter of satisfaction to know that results have justified the view we took then.

EXPLANATION OF PLATES.

PLATE 2.—Map of Bawdwin Mines, from a survey by Dr. J. M. Maclaren. (Supplied by the Burma Mines Co., Ld.).
PLATE 3.—Plan of Workings at Bawdwin. (Supplied by Burma Mines Co., Ld.).
PLATE 4.—Plan of Faulting on the 171-feet level.
PLATE 5.—Generalised section along the ore-channel at Bawdwin.
PLATE 6.—Sections along AB and CD (Pl. 8).
PLATE 7.—Geological map of Bawdwin (1″=1 mile).
PLATE 8.—Geological map of Bawdwin and neighbouring country (1″=4 miles).

[1] The tunnel was connected through in September, 1916.

MISCELLANEOUS NOTES.

Monazite in Mergui and Tavoy.

While in Mergui in August, 1916, I spent four days panning on the Shwe Du and Lamawpyin chaungs, in order to form an idea of the values of a monazite-bearing sand which I had obtained from them. These streams drain the south-west side of the Anatholin range, a granite ridge 900 feet high, which forms the backbone of the island on which the town of Mergui is built, and is surrounded by sedimentary rocks belonging to the Mergui Series. The mineral occurs on the north-east side of the ridge as well. The courses of the streams are very steep where they traverse the granite, and there no accumulation takes place, but in the flatter country occupied by the Mergui sediments a considerable thickness of gravels and soil is found.

Twenty-eight stations were taken for sampling, as far as possible representative of different conditions of accumulation, *e.g.*, on the edges of the streams, from gravel bars, from varying depths below the stream-beds, in pools below cascades, from the stiff white clay which underlies the gravels and at different depths in the alluvium of the valley flats.

The richest sample gave a calculated result of 6·3 lbs. of heavy concentrate per cubic yard—from a loose gravel bank in the Lamawpyin chaung—and the poorest ·2 to ·4 lbs. per cubic yard, these being from the flats a little distance away from the streams. The average value was 1·2 lbs. per cubic yard.

The heavy sand is uniformly fine and in well-rounded grains. Ilmenite is the predominant mineral present and next in quantity is the monazite. A little magnetite occurs, bright red grains (garnet or spinel), an occasional show of gold, and a trace of tin has been detected by qualitative analysis, but tungsten is absent. Zircon has not been detected unless extremely fine greyish particles, with high lustre and which hang behind the rest of the concentrate in panning, are zircons.

The higher portion of the sand which passes off in washing consists of quartz, felspar, biotite and tourmaline, with kaolin, hydrated iron oxides and rock fragments. The thorium-bearing mineral occurs as opaque greenish-white grains. A quantitative analysis, for which I am indebted to the Curator of the Geological Museum and Laboratory, showed that there was 1·61 per cent. of rare earth oxides present in the concentrate, and, assuming the thiosulphate method of estimating thorium to be accurate (zirconia would, if present, interfere with this method), there would be about 0·18 per cent. of thoria in the heavy sand or on the average 0·00216 lbs. of thoria (ThO_2) per cubic yard

of the ground sampled. Such a minute fraction is of course of no practical utility.

I have found the same greenish-white mineral in a black sand, naturally concentrated by wind, which occurs in small patches on the sea-shore near some granite rocks, 1 mile north-west of the mouth of the Kyanchaung, in the south of the Tavoy district.

In the Tavoy district monazite has also been recorded from Messrs. Booth and Milne's tin dredge at Taungthonlon, and, doubtfully, from the Heinze Basin.

[A. M. HERON.]

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1917. [November

THE BIANA-LALSOT HILLS IN EASTERN RAJPUTANA. BY A. M. HERON, B.Sc., F.G.S., Assoc. Inst. C.E., *Assistant Superintendent, Geological Survey of India.* (With Plates 9-12).

INTRODUCTION.

THESE hills form an area almost entirely isolated by alluvium from the extensive outcrops to the north, described in my memoir on the geology of North-Eastern Rajputana, and show in their stratigraphy and in the amount of folding, alteration and igneous intrusion, which the constituent beds have undergone, various important differences from the rocks of the same age in that region. To the south they are completely separated by alluvium, and by one of the two great boundary faults of Rajputana, here concealed by surface deposits, from the plateau of Upper Vindhyan rocks described in my account of the Gwalior and Vindhyan systems in Eastern Rajputana; at the eastern end of the hills, near Biana, this alluvium has a breadth of only four miles, and the scarps of the Alwar series and the Upper Bhander sandstone face each other across the narrow gap, giving from their proximity an excellent opportunity of comparing their distinctiveness in lithological composition, in the alteration and folding to which they have been subjected, in the topography to which they give rise and even in the amount and character of the vegetation on their surface.

Biana (Bayana) is the junction for the Agra branch on the Bombay, Baroda and Central India railway route from Bombay to Delhi,

broad gauge, and is the only point at which these hills are accessible by rail. The area is very conveniently divided into two sections, the Biana hills and the Lalsot hills, united only by a narrow ridge, Biana (26° 55′: 77° 21′) being at the extreme east and Lalsot (26° 34′: 76° 23′) at the west of the two sections, the two places being 63 miles apart. The total length of the hills, measured along their general north-east—south-west trend, is about 75 miles and their breadth 8 to 10 miles. Politically the Biana hills lie in the Bharatpur State and the Lalsot hills in the Jaipur State of the Rajputana Agency, and I would here acknowledge my indebtedness to Lieutenant-Colonel B. E. M. Gurdon and the late Leiutenant-Colonel H. L. Showers, who were then in political charge of these States, for assistance and facilities enjoyed during my work and for much personal kindness.

The geological survey of this area was carried out in March 1911 and January and February 1912, as part of the general revision of the Rajputana survey, under the superintendence of Mr. C. S. Middlemiss. Mapping was done on the Survey of India Standard sheets, 1 inch=1 mile.

In his two papers on the geology[1] of Rajputana Mr. C. A. Hacket has very briefly alluded to this tract, and my re-survey is a considerable amplification of his work, although based on it.

The formations which occur are two :—

(*a*) the schists, granites and pegmatites of the Aravalli system and

(*b*) the quartzites, conglomerates, shales and trap, belonging to the Alwar series, the lower of the main and persistent subdivisions of the Delhi system. The beds of the Delhi system rests on the Aravallis with a profound and exceedingly distinct unconformity and are folded into them, in the Lalsot hills at least, in a series of synclines, the intervening anticlines being as a rule worn down by denudation and the older rocks exposed along their axes.

The Raialo quartzite and limestone, which in the south of Alwar form a local subdivision of the Delhi system resting on the Aravalli system below the Alwar series, are here absent from the sequence, and the Kushalgarh limestone, the hornstone breccia, and the

[1] *Rec., Geol. Surv. Ind.*, Vol. X, 2, p. 87; *Rec., Geol. Surv. Ind.*, Vol. XIV, 4, p. 298.

Ajabgarh series, which normally succeed the Alwar series, are not seen, as none of the sections here extend upwards far enough to include them. They may be present in some of the synclines, but, if so, they are buried beneath alluvium, except in one doubtful case. As far as this area is concerned therefore, the terms Delhi system and Alwar series are synonymous.

The rocks of the Aravalli system will be described first, from the east of the area westwards, and then the Delhi system in the two geographical divisions into which it naturally falls, the Biana and the Lalsot hills.

Table of formations.

GROUP	SYSTEM.	SERIES.	STAGE.	—
			(Biana Hills only.)	
			Weir stage—	
PURANA GROUP	Delhi system.	Alwar series	Quartzites . . 2,500 ft.	
			Shales . . . 300—400 ft.	
			Trap band.	
			Damdama stage—	UNCON-FORMITY.
			Thin-bedded sandstones and shales . . } 4,000 ft.*	
			Massive quartzites . }	
			Conglomerates . .	UNCON-FORMITY DOUBT-FUL.
			Biana stage—	
			Quartzites . . . 1,100 ft.	
			Badalgarh stage—	
			Flagstones and shales . 600 ft.	
			Nithahar stage—	
			Quartzites . . . }	
			Tuffs, trap, etc. . } 3,500 ft.	
			Quartzites . . . }	
			Basal conglomerate . }	
				EPARCH-ÆAN UNCON-FORMITY.
ARCHÆAN GROUP.	Aravalli system.	Phyllites, quartzites, etc. Granites and pegmatites, intrusive in Aravalli system.		

Aravalli System.

The outcrops of the metamorphic rocks belonging to this system, and of the granites and pegmatites intrusive in them, form a very narrow band, at the foot of the scarps of Alwar beds, which have protected them from entire removal, around the borders of the synclines. Although they disappear beneath alluvium at a very short distance away from these scarps, an enormous thickness of them is represented, for their strike is at nearly a right angle to that of the overlying Alwar beds (Pl. 10, fig. 1). In his earlier paper Hacket calls them the "Schist Series" and in his later paper puts them into the Aravalli system. It is of course impossible to prove that they are of the same age as the similar rocks, penetrated by similar granites, which occur below the base of the Delhi system in the south of Alwar, but there is every likelihood that they are of the same age. In the Biana hills they are found below the scarp of the Nithahar quartzite, the lowest division of the Alwar series, for a distance of about fourteen miles. In spite of the very great thickness exposed—for the narrow band of outcrop runs almost perpendicularly to their strike—, they show little variation in their character. For the most part they are silvery, buff or reddish talcose phyllites, with bands of quartz-talc schist, and soft, rusty, argillaceous quartzites. The dominant strike is north-east or north-north-east and the dips high and irregular, varying to both sides of verticality. The band of Aravalli rocks and certain of the overlying stages are repeated by a strike-fault. The minimum alteration in the Aravallis is seen at Kondra (26° 57': 77° 2'), where the group of hillocks standing out on the plain in advance of the scarp is composed of indurated, very slightly altered, pale and dark-grey, thick bedded clay-rocks, not even slates, a great contrast to the schists of the same system to the west; and yet they are clearly overlain by the hard and vitreous, but much younger, Nithahar quartzite of the scarp. The very moderate alteration of the Aravalli rocks, as well as the comparatively gentle dips of the Delhi beds shows that this region has escaped the intenser plications of the Aravalli Range.

For a considerable distance along the base of the ridge connecting the Biana with the Lalsot hills, from Kondra to Morra (26° 49': 76° 52'), the Aravalli system is not seen, but the lowest Alwar beds exposed form a thick band of rock—similar to the Kondra clay-rocks

and evidently composed of their re-assorted débris—all the way along the foot of the scarp.

At Morra the Aravalli beds are olive-green and brown talcose phyllites and schists, more altered than those at Kondra. Farther west, at Kamalpur (26° 48': 76° 49') they are mica-schists with pegmatite intrusions. The small outlying hills at Pahari (26° 47': 76° 56') and Talchiri (26° 54': 77° 5') are ridges of vertical, copiously jointed and quartz-veined quartzite, with, to the south of Pahari, a small outcrop of arkose grit, almost indistinguishable from granite, like which it weathers.

The Aravallis are not seen again to the south-west up to Lalsot, at the other end of the hills. At Lalsot they are mica-schists, resembling compressed grits, banded along the strike with medium to coarse-grained pegmatite in rough lenticles and streaks, twisted and pinched out irregularly[1]. In places the schist is quite free from pegmatite, in others the pegmatite greatly predominates. The difference in strike between the beds of the Delhi and Aravalli systems respectively is very marked, that of the latter being constant in a north-east—south-west direction and that of the former curving from east-north-east—west-south-west to north-west—south-east. The junction is well seen immediately to the west of Lalsot; the pegmatite, locally unmixed with schist, is closely adherent to the basal bed of the Alwar series, a compact black vertical quartzite, with a line of pebbles of pegmatite and of vein-quartz at the contact. The quartz-veins from which the latter are derived traverse the pegmatite and are cut off sharply at the old denuded surface, projecting slightly from it by reason of their superior hardness, in the same way as do the aplite veins at Gisgarh (p. 186).

At intervals all along the north-western side of the long valley opening near Lalsot and extending up to Lalsir (26° 45': 76° 39'), pegmatite-veined Aravalli beds are seen; on the other flank no exposures are available.

The actual junction is almost always hidden by scree-material, but at the base of the scarps, from the opening of the valley, *i.e.*, its south-west end, as far up as Moran (Garh on the map, 26° 43': 76° 36'), Delhi and Aravalli beds are seen almost in juxtaposition and agreeing in their general strike. There is, however, no doubt

[1] The detached hill at Chondias, four miles west of Lalsot, is of ordinary massive granite carrying veins of tourmaline pegmatite.

about the unconformity, as the pegmatite veins in the Aravalli rocks are all truncated on a horizon of conglomerates composed of pebbles of arkose and quartz, constituting the base of the Alwar series. Beyond Moran the base is more sinuous and is seen to cross the strike of the underlying Aravalli beds. It is curious that the felspar pebbles in these conglomerates are all salmon-pink or reddish, while the felspars of the underlying pegmatites are white, or at the most pale pink; this indicates that the conglomerates are not derived from material *in situ* immediately below, but from the massive granites to the north the felspars of which are strongly coloured.

The Rupali hill, 1 mile south-east of Garh, is composed of dark-rusty and vitreous quartzites, impure slaty limestones and amphibolites of the Aravalli system.

In the Gudho (26° 47': 76° 43') valley, eroded along an anticline of the Delhi beds like the preceding valley and really a continuation of it but not on the same anticline (p. 197), granite is exposed at only two points within the inward-facing scarps. It is of the same type as the Aravalli granite of Parla[1]; it is porphyritic, strongly biotitic and devoid of pegmatite veins, and has the phenocrysts distinctly arranged in lines.

In the Gisgarh (26° 53': 76° 42') anticline, the Aravalli granite is more extensively exposed than elsewhere, with very clear sections of the unconformity. It forms a prominent irregular glacis below the scarp, which has at its base reddish quartz-mica schists with felspathic layers, and locally, resting on the granite, a layer of fine conglomerate composed of quartz and felspar pebbles in a black matrix. The schists, it is clear, have originally been arkose grits derived from the disintegration of the underlying granite, and are now greatly compressed. The surface of contact of the granite is very even, a few veins of harder, aplitic material project for a few inches into the overlying grits, and broken-off portions of this lie imbedded in them, partially rounded but not transported to any distance from their place of origin. The two detached hills at Giltari and Karolian also show the unconformity well; at the latter place there is some amphibolite veining in the granite, doubtless connected with certain epidotic and calcareous slates in the overlying Alwar beds, which greatly resemble altered tuffs.

[1] *Mem., Geol. Surv. Ind.*, XLV, p 19.

Taking the Biana-Lalsot tract by itself, the relationship between the pre-Delhi granites and the Aravalli metamorphics is doubtful, for the two are never found in contact, but in the country to the west—southern Jaipur—granites of exactly the same type as the above were found to be clearly intrusive in Aravalli schists, so that in the present area there is every probability that the metamorphic rocks are the older and that the granites were intruded into them, and the whole complex was denuded before the beds of the Delhi system were deposited.

It has been seen that, proceeding from east to west along the range there is a progressive increase in metamorphism in the Aravalli sediments—accompanied by an increase in the amount of igneous intrusion—from phyllites and argillites to mica-schists injected with pegmatite, and unmixed granites. The overlying Delhi beds share in this, at least with regard to alteration, and its cause is that, going westwards, the core of the ancient Aravalli range is approached, where compression by folding, deep-seated metamorphism and igneous intrusion reach their maxima.

The Delhi system : *Alwar series.*

BIANA HILLS.

The Biana hills are peculiar amongst the areas of the Delhi system in the comparatively low dips of the beds throughout, 20° being about the average, and that here the Alwar series can be divided into several stages by unconformities and differences of lithological character. Hacket[1] has adopted five, to which I have adhered, (see Table of formations) and mentions one unconformity and several conglomerates indicating breaks in the succession.

The Raialo quartzite and limestone, a local division forming in Alwar the base of the Delhi system, below the Alwar series, is here not developed, and the beds above the Alwar series are, if present, concealed by alluvium, so that here and in the Lalsot hills the latter series is the sole representative of the Delhi system.

In the Biana hills the conglomerates are extremely variable and occur in force only at their eastern end and in the middle stages, the Damdama and the Biana, so are of little value in

[1] *Rec., Geol. Surv. Ind.*, Vol. X, 2, p. 87; *Rec., Geol. Surv. Ind.*, Vol. XIV, 4, p. 298.

correlation; Hacket in fact arrives at his divisions without taking them into account. All the stages, especially the Damdama, decrease in thickness from east to west, and the uppermost, the Wer stage, overlaps the three middle formations and is finally found in juxtaposition with, and apparently conformable to, the Nithahar stage. It is probable that, as well as an overlap, there is an actual dying out of the middle formations, as indicated by their visible diminution in thickness; to the west, however, the sections are unfortunately very incomplete. Hacket believed that the Nithahar stage also died out, the Wer overlapping it on to the Aravalli beds. In this I disagree with him, for I can find no evidence for it and the rocks of the ridge connecting the Biana and Lalsot hills, which he considered to belong to the Wer stage, resemble the Nithahar much more closely than they do the Wer.

As has been stated, in these hills the dips of the Delhi beds are much lower than is usual, being between 10° and 20° throughout most of their extent, but at the west end the strata gradually become steeper in inclination and concurrently more metamorphosed. Along the eastern two-thirds of their length the dips are to north-east and north-north-east, in the western third swinging round to north-west, and at the extreme eastern end also they dip to the north-west for a short distance.

In my memoir on the Delhi system in North-Eastern Rajputana,[1] I have suggested that the change in the character of the rocks of the Alwar series, as one passes northwards from the outcrop of their base on the Alwar-Jaipur frontier, from beds denoting littoral conditions to a facies of deeper water accumulation, is due to the derivation of their materials from a land area in existence somewhere to the south of their present southern margin there. In the Biana hills the great thicknesses of conglomerate, the considerable accumulation of tuffs and effusive lavas, and the unconformities and overlaps, are still more indicative of littoral and terrestrial conditions and of those oscillations of level which take place on a continental margin, and we may safely assume that the land area from which those sediments were derived was close at hand on the south or south-east. We know nothing of the distribution of the earlier Purana rocks or of the configuration of the pre-Delhi land-surface over the adjoining regions in south-eastern Rajputana and the major portion of Central India, for the Vindhyans and the

[1] *Mem., Geol. Surv. Ind.*, XLV.

Deccan Trap cover all. It is possible that the apparent absence of the Delhi system over a large portion of central Jaipur (to the west and north-west of the present area) may be a real absence, due to the presence there also of a raised area or island at the time of their deposition,—a land-mass which supplied from its disintegration part of the materials for the beds of the Delhi system in Alwar, for those of the Lalsot-Biana hills and for the immense pile of conglomerates seen in the Lalgarh hills to the north-west. It is significant that, from the scanty evidence we have, the locality of this hypothetical island is distinguished by the presence of granite to the exclusion of other Aravalli rocks, which is what we should expect, for a large granite boss natuially gives rise to high ground from its superior resistance to denudation as compared with the softer phyllites and schists. In Bundelkhand again we have exposed a vast granitic or gneissic area, which would be, on my assumption, a part of the other or main land surface around which the Delhi and succeeding Purana systems were deposited.

(*a*) *Nithahar Stage.*

The Nithahar stage is the lowest division of the Alwar series, and supervenes immediately above the Aravalli System. At the base is a conglomerate formed of imperfectly rounded pebbles of white quartz and fragments of the underlying Aravalli phyllites in a yellowish argillaceous matrix, also derived from the phyllites; the greatest thickness seen, about 10 ft., was observed at Nithahar, but along most of the junction it is very much thinner; evidently such soft rocks as the phyllites do not tend to the formation of conglomerates from their disintegration. The lower beds of the Nithahar stage are pale in colour, fine-grained and vitreous—quartzites in all respects typical of the Alwar series.

Near the middle of the stage are two zones of volcanic rocks, of which the upper is much the thicker, comprising numerous agglomerates, tuffs, vesicular traps and dark ferruginous quartzite—clearly the results of contemporaneous volcanic activity—, interbedded with quartzites. The bands are too thin and too numerous to be mapped individually. The traps are extremely tough, green, sparingly pointed rocks, often vesicular, and are none of them thick, nor does any thickness of them occur without intercalation of tuff or quartzite. Under the microscope they are seen to be highly altered mineralogically, but their crystals are quite undeformed. They

appear to have been dolerites, in which the laths of plagioclase are completely changed to saussurite and the augite to irregular masses of chlorite. Leucoxene is also present There is none of the wholesale recrystallisation and formation of hornblende and secondary felspars which are seen in the amphibolites of the same or younger age in the Delhi system elsewhere and which are due to folding and deep-seated metamorphism which these have escaped. The tuffs and agglomerates are composed of angular fragments of quartz and quartzite, with rounded greenish pieces of trap and green devitrified volcanic glass.

The lower volcanic zone is about 400 ft. thick, the upper about 1,600 ft. at its maximum development, but it dies out rapidly to the south-east. The total thickness of the Nithahar stage is some 3,500 ft. Above the volcanic beds the rocks are similar to those below.

Near Sita (Silagaon of the map, 26° 59′: 77° 11′) are several local conglomerate bands, one of them extremely coarse and very thick, and all copiously impregnated with iron-oxide in the cementing material in the interspaces, giving a dark purplish hue to the rocks. The pebbles in them include white vein-quartz, jasper rock, white, grey and black quartzite, and conglomerate, in a ferruginous matrix. No gneiss, granite or schist pebbles were seen.

About 2 miles west of Sita, two large dykes cross the strike the longest 1½ miles long, of a soft, foliated, ferruginous quartz chlorite schist, the decomposition product of a basic dyke-rock. They are probably feeders of the lava flows, from the horizon of which they extend downwards.

As is to be expected from their nature and their lie, the beds of the Nithahar stage give rise to a succession of nearly vertical scarps backed by dip-slopes with a declivity of 10°-20°.

West of Sita the Nithahar stage is topped by the Wer stage—their mutual relationship will be described when treating of the latter. East of Sita it passes up conformably into the Badalgarh stage; the actual junction is concealed by débris at the base of a bold cliff formed by the Badalgarh stage, a cliff which runs continuously through the hills, but there is no evidence to suggest an unconformity.

(*b*) *Badalgarh Stage.*

The Badalgarh stage forms a very distinct division, about 600 ft. thick, composed of argillaceous (sometimes gritty) flagstones

with shaly and micaceous layers. Being heterogeneous and easily eroded their preservation is due to the hard Biana quartzites capping the scarp and preserving its verticality. In a gorge, 1 mile south-east of Sita, is seen a local unconformity between the Badalgarh and the Damdama stages, the intervening Biana stage being over-lapped (*v. infra*); elsewhere the Biana stage follows conformably on the Badalgarh.

(*c*) *Biana Stage.*

Hacket describes the Biana stage as "a white quartzite containing many bands of conglomerate," a rather misleading description, as the quartzites are all pink or pale reddish-purple and the conglomerate bands occur only at the extreme eastern end of the hills, dying out within a quarter of a mile. Like the other stages, the Biana has its maximum thickness, about 1,100 ft., at the east, thinning gradually westwards. It consists of pink and pale reddish-purple quartzites, fine-grained, homogeneous and with jointing and bedding not very evident.

The junction between the Biana and the next succeeding stage, the Damdama, is always poorly exposed; towards the top of the Biana stage pebble bands occur and there seems to be a gradation upwards into the thick conglomerates of the Damdama stage, but this may be deceptive and the junction really an unconformity. The break between the Badalgarh and the Damdama stages to the south-east of Sita is very clear. At the entrance to the gorge the Badalgarh stage forms the usual cliff, capped, not by the Biana quartzite as usual, but by the basal bed of the Damdama stage, which lies at an inclination slightly differing from that of the Badalgarh and so truncates the beds of the latter stage one after another. Near the head of the gorge a conglomerate layer comes in at the base of the Damdama stage, rapidly increasing eastwards to a great thickness and below this the Biana stage appears, thin at first. It is uncertain whether the unconformity between the Badalgarh and the Damdama stages is merely local or is continued between the Biana and the Damdama after the former attains its normal thickness.

(*d*) *Damdama Stage.*

The Damdama is by far the thickest of the stages and increases in thickness more rapidly from west to east than any of the others, owing to a vast accumulation of conglomerates in its lower portion.

Midway along its outcrop it must be about 4,000 ft. thick and is still thicker further to the east. In the conglomerates the following rocks occur as pebbles: white vein quartz, dark quartzite of several hues, jasper rock, vesicular trap, greenish Aravalli indurated shale and phyllite, and quartz-tourmaline pegmatite, all quite unflattened by crushing though often cut through by joints. The topmost beds, forming the dip-slopes south of Lakhanpur (26° 59': 77° 13') are dark red and purple, fine-grained, massive quartzite; through them ravines are cut along the dip, exposing the conglomerates and pebble-bands underlying them. Just north of Lakhanpur is a low ridge of thin-bedded, dark quartzitic sandstones and black shales, higher in the succession than the massive quartzites.

(*e*) *Wer Stage.*

The next and highest stage, the Wer, is separated from the other stages by a distinct unconformity. It is divisible into two portions, the lower of black shales, the upper, and much thicker, of quartzites, but the outcrops of this group are very fragmentary and broken up by spreads of alluvium. The shales are mapped by Hacket as Damdama, although, in his table of formations, he mentions no shales in the Damdama stage, but "black slaty shales" in the Wer. The junction between these shales and the Damdama beds is covered by alluvium, but the strike of the Wer quartzites is closely parallel to that of the shales and both strike for some distance at a considerable angle to Damdama beds. The shales also extend for a long distance further west than the Damdama stage and overlap it, finally resting on the Nithahar beds. It is therefore obvious that the shales should be placed in the Wer stage and that there is an unconformity between it and the Damdama.

From Sita (Silagaon) north-westwards along the strike of the Wer stage, the Nithahar beds are crossed at a low angle to their strike, the end of one bed after another passing in succession below the alluvium in the space separating them from the Wer stage. North of Hathori (27° 0' : 77° 10') is a thick trap band, less altered than those in the Nithahar stage, with a vesicular crust and succeeded upwards by a quartzitic sandstone. Its base is not seen. It is highly probable that this is a flow poured out on the old land surface at the horizon of the unconformity at the base of the Wer stage. Above this sandstone are the shales, intercalated at their top with

felspathic grits and passing upwards into quartzites; the shales are here 300 to 400 feet thick.

The Wer quartzites are white or pale yellow, hard and free from impurities or from interbedded layers of shale, sometimes vitreous, sometimes granular, massive and almost unbedded and with close and very irregular jointing. They form bold castellated ridges, with their slopes buried in large fallen blocks. To the west, and also near their base, they are more regular in bedding and jointing. The separate fragments commonly weather with a surface covered with small brown dots and pittings, probably where a grain of pyrites has oxidised into the matrix. The thickness of the quartzites is about 2,300 feet at least, but their true upper limit is probably not seen.

LALSOT HILLS.

The Lalsot hills are connected with the exposures of the Alwar series in the type area by two virtually continuous ridges, so that there is no doubt whatever about their correlation with them. A continuous line of outcrop of beds at the base of the series carries on the correlation from Morra in the Lalsot hills to Kondra at the western end of the Biana hills, so that the latter again are linked up through the Lalsot hills with the Alwar beds of the type area. The connecting ranges will be described first.

On each side of the syncline, on the Alwar border, in which the Ajabgarh beds of Mandaor[1] lie, are inward-dipping ridges of Alwar rocks, the more westerly of which has at its base Aravalli granite. They run south across the Banganga river, approaching each other and steepening in dip to verticality and, with trifling breaks, pass into the Lalsot range. From where they join it another narrow line of quartzites, dipping at 70° or more to the south-east, runs north-east to meet the Alipur ridge[2] in which both Alwar and Ajabgarh beds are present (section B B). North of Toda Bhim (26° 55′ : 76° 52′) the anticline *cd* has narrowed by the pitching of the axis of the fold, while to the south-east (at Toda Bhim) commences another parallel anticline, bounded by inward-facing Alwar scarps and occupied by Aravalli beds (p. 185) almost completely concealed by alluvium.

Section CC shows the beginning of this anticline (*jk*) *a* being the reappearance of the Aravalli granite below the Gisgarh scarp

[1] *Mem., Geol. Surv. Ind.*, XLV, p. 76.
[2] *Mem., Geol. Surv. Ind.*, XLV, p. 84.

and *h* where the metamorphics at Morra continue the unconformity of the Biana hills. A little distance to the south-west of the line of this section the minor flexure *cd* dies out and *be* becomes a simple syncline. At Gisgarh the basal beds are red quartz-mica schists with felspathic layers, and compressed arkose grits, derived from the disintegration of the underlying granite; locally, a layer of fine black conglomerate, with quartz and felspar pebbles, lies on the granite. Above these are banded and well stratified pebble-conglomerates, the pebbles chiefly of quartz and smaller than walnuts. There is nothing here analogous to the great accumulations of coarse conglomerates seen at points on the unconformity in Alwar. Following upwards in the section is a cliff of reddish and dark grey, compact quartzite. The two detached hills north of Gisgarh, in both of which the unconformity is displayed seem to have been faulted to the north-west. In one of these, and also 2 miles to the south of Gisgarh, are seen banded epidotic and calcareous slates, which greatly resemble altered tuffs and are probably connected with trap veins in the underlying granite; in the whole of the Lalsot hills these are the only representatives of the basic intrusives so frequently met with in Alwar.[1]

The general facies of the rocks here and on the other flank of this anticline, *ab*, is much more argillaceous than the typical Alwar beds. The quartzites are darker and more ferruginous and numerous slate bands occur not far from the base; the purer quartzites are very vitreous, but the slates are not at all schistose. A narrow synclinal valley, *be*, separates, this from the main or central anticline, *jk* (section CC).

The ridge joining the Biana and Lalsot hills Hacket believed to be composed of the Wer stage, the Nithahar having died out and the Wer overlapping it on to the Aravalli beds. I am convinced that he was mistaken in this, for I can find no evidence to support it and the dark grey and purple quartzites with argillaceous bands are much more similar to the dark-hued and heterogeneous Nithahar beds than to the pale-coloured and purely siliceous Wer quartzites. The explanation is probably that, through steepening in dip, the outcrops of the beds of both stages have diminished in width and that the Wer stage is absent, by denudation, from the connecting ridge, but reappears in the plateau north of Morra, where, however, the higher inclination of the strata and absence of good sections

[1] *Mem., Geol. Surv. Ind.*, XLV, pp. 38, 90.

prevent separation of the stages. It is possible, too, that with distance from the presumed original margin of deposition of the stages, accumulation may have been continuous and the unconformity has disappeared; if present, it is certainly not shown by a conglomerate, by lava-flows, or by any marked disparity in the dip or strike of the strata.

Along the base of the ridge the pre-Delhi unconformity is concealed but a thick band of rock occurs, lithologically similar to the Aravalli types seen at Kondra, and is probably the result of their disintegration. A thin quartzite intervenes between this and other similar beds, in places a fairly pure hardened pipe-clay, slightly mottled with pale purple and pink, which is used in the adjacent villages as a whitewash. The ridge is perfectly straight and vertically bedded as far as Morra. West of Morra, a couple of sharp parallel folds bring the unconformity above the surface of the alluvium; and arkose gritty beds, with conglomeratic and slaty layers, are seen to intervene between the above-mentioned argillaceous beds and the Aravalli outcrops. It is more than probable that the steatite deposits of Morra and Dhawain (near Kamalpur), which are on the continuation of the former, have been formed by the concentration of the talcose schists below, just as the white clay band has been formed from the soft Aravalli rocks of Kondra.

Passing from Kamalpur towards the central anticline the edges of the basement beds are crossed obliquely where they run below the alluvium, and they are not seen again on this side of the central valley until they re-emerge near Lauali (26° 34′ : 76° 33′) at the other end of the hills; between these places the south-eastern margin of the central longitudinal valley there is a straight and narrow ridge of rocks near the base of the series but on the other flank of the syncline *fg*. Between this ridge, the beds of which dip to south-east, and the north-west or north-north-west-dipping strata of the Morra plateau is a synclinal, or rather isoclinal, valley, *fg* (section CC) in the centre of which near Berod (26° 51′ : 76° 49′), is a small hill of black slates which may belong to the Ajabgarh series.

At the end of the central anticline near Toda Bhim, the beds of the Alwar series form a steep-sided plateau (*málз*) in which the dips are nearly vertical, but indistinct owing to the compression which the rocks have undergone. They are fairly white quartzites, but many of the beds weather in a curious cellular fashion, with irregular

or lenticular cavities formed by the removal of ferruginously cemented material, often leaving a quartz sponge.

As far to the south-west as Pail (26° 45′ : 76° 40′) the anticline is a simple one bounded by two narrow ranges, that on the north-western side consisting of massive dark quartzites, with paler bands, showing bedding well and dipping outwards at 60°—75°, the other of reddish, thin-bedded, porcellanic quartzites and dark massive quartzites with black slates above, *i.e.*, towards the south-east. The latter beds are inverted, dipping in the same direction and at the same angles as the opposite ridge. This is analogous to the westward- or north-westward-dipping isoclines which are so common in the Delhi system elsewhere.

Aravalli granite is exposed at only two places within the bounding ranges (p. 186).

At Pail the structure becomes somewhat complicated. The valley narrows to a mere passage between the hills, in which quartzite is exposed, thus isolating the (hidden) expanse of Aravalli beds in the north-eastern or Gudho section of the valley from those in the south-western portion. At the same point the narrow south-eastern ridge abruptly expands into a triangular plateau on which conglomerates are seen, and rapidly contracts again to a line of outcrops as straight as, and even narrower than, before. The north-western ridge bends sharply through a right angle and then again back to its original direction, becoming simultaneously an elongated and level-topped table-land four or five miles wide. At Pail, and for two miles to the north, the outcrops of the beds stop along an almost straight line, presenting their ends to the valley, with long ravines running up from it along their strike. It is probable that here and at the other sudden change of direction there are "tear-faults," or lateral fractures of the strata at the point of flexure, these accounting for the termination of the outcrops (which takes place at both ends of the section where the beds strike north-west—south-east) along straight lines perpendicular to their strike. At Pail a considerable thickness of arkose grits and conglomerates appears in the section, but these die out or pass into normal quartzites a short distance along the strike.

It is evident from the very marked disparity in the thickness of strata exposed on either side of the south-western portion of the valley, in which is situated Moran (Garh on the map, 26° 43′ : 76° 36′), that the anticline is not now a simple one in continuation of that just

described, between Toda Bhim and Pail. The following explanation is a reasonable one and fully borne out by the field evidence. The axis of the north-eastern, or Gudho, anticline, instead of being continued straight on through the south-western, or Moran, portion of the valley, swings to north-west near Pail and passes along the plateau towards Karomar (26° 39′ : 76° 30′), at the same time pitching downwards so that the underlying Aravalli beds no longer appear along the crest but are concealed under the Alwar series. Near Karomar the axis rises again and the Aravalli system though covered by alluvium, is inferred to be free from the superincumbent Alwar series, for the beds appearing in the inward-facing scarps are characteristic of the base of the series. The Moran (Gaih) valley is, however, clearly an anticline, the axis of which has pitched high enough to bring the easily denuded Aravalli beds to the surface, but it is not a direct continuation of the Gudho anticline. The plateau bounding the Moran valley on the north-west is there made up of an anticline and a syncline of Alwar beds, the anticline being a continuation of that of Gudho, but it does not give rise to a valley until the axis pitches high enough to carry up the Aravalli rocks, and the syncline intervenes between it and the Moran anticline. The latter is a new fold, *lm* (section EE), which has come in, with its parallel syncline lying to its north-west, between the anticline, *jk*, and the syncline, *fg* (sections DD and EE). In other words, although the Gudho and Moran valleys are topographically continuous, they are not so geologically, for the Gudho valley is structurally succeeded on the line of the same anticline by a plateau and then by a valley, while the Moran valley, its geographical continuation, is on another and parallel anticline. The axis of the Gudho-Karomar anticline, *jk*, probably passes through Jaharo, 1 mile to the north of Pail, and the conglomerates of Pail are some distance above the base of the Alwar series.

The south-eastern boundary ridge of the Moran valley is largely composed of fine-grained, red, yellow and white, splintery, porcellanites and slaty quartzites; along the top runs a band, about 20 yards wide, of white and rather impure kaolin inter-banded with quartzite. Towards Lauali the ridge broadens greatly from the emergence of a considerable thickness of beds which have been concealed beneath alluvium and are the continuation of those about Kamalpur (p. 185). The actual base of the Alwar series at Lauali is not seen. The lowest beds exposed are schists and schistose conglomerates,

some of the latter being fairly coarse, the pebbles of which are mainly of vein quartz and quartzite, with some of black chert. To the north of Lauali the ends of higher beds are crossed, but the basal conglomerates run from Lauali south by west to the end of the syncline, *mh* (sections EE and FF), at Binoli.

The aspect of the plateau on the north-western flank of the valley is the normal one of these *málas*,—almost level, with strike gullies and ridges caused by the differences in resistance of the beds, and covered with sub-angular boulders and a sandy soil supporting thin grass and bushes of "dhao" (*Anogeissus pendula* and *latifolia*), with small "dhak" (*Butea frondosa*) trees in the hollows. Being uncultivated, these elevated tracts are resorted to by communities of herdsmen of the Gujar caste, with their flocks, during the dry season, when pasturage on the plains is insufficient; there the Gujars remain until the water stored in shallow tanks is exhausted, when they descend to the lowlands. I have elsewhere[1] ascribed the striking levelness and equality in height, of these tracts to their being remnants of a former base level of denudation probably of Jurassic times.

The rocks are alternations of coarse and fine, ferruginous, dark and mottled quartzites. Along the axis of the Gudho-Karomar anticline, are soft brown quartzites, by the erosion of which a shallow valley has been formed on the plateau, in which are the permanent villages of Dhowa and Sir. All the rocks are much altered (stratification being often quite obscured), the finer quartzites being vitreous and excessively jointed and quartz-veins are common. As throughout the Lalsot-Biana hills, there are, however, no signs of the intrusive amphibolites, granites and pegmatites characterising the Alwar series in other areas.

In the Karomar valley no granite or Aravalli schists are exposed; but at Gol, opposite Karomar, there are in the Alwar series arkose grits and conglomerates, indicating the proximity of the basal unconformity; and at Lalsot, below a ridge undoubtedly continuous with that of Gol, the junction is admirably shown. The form of the valley and the dips of the beds on either side support the idea that it is eroded along a tongue of Aravalli rocks extending into the hills along an anticline.

At Lalsot the basement bed of the Alwar series is a compact black vertical quartzite, with a line of pebbles of pegmatite and of

[1] *Mem., Geol. Surv. Ind.*, XLV, p. 32.

vein-quartz at the contact. Grits occur but are not at all in force; this section again shows that a violent unconfoımity may occur without the formation of conglomerates. The black colour of the basement bed, like that at Gisgarh (p. 194), suggests the carbonaceous soil of an old land surface.

MINERALS OF ECONOMIC VALUE.

Copper.

Nithahar. A mile west of Nithahar is a small copper working in the Nithahar beds; it is a narrow and inclined open-cut. No trace of a vein was visible and practically no ore was to be seen strewn about.

Hathori. Another disused copper mine is said to be situated to the south or south-west of Hathori, but I could neither find the mine nor anyone who knew its location.

Lalsot. ½-mile north of Lalsot in the Alwar quartzites a shallow open cutting has been sunk for a few feet along the hill and some of the débris lying about shows films of green copper carbonate.

Moran. In the Rupali (map: Rupalee) hill, ½-mile south-east of Moran (Garh), there are several small pits at the north-eastern end of the hill, but I could find no trace of any copper ore, nor of the shaft, 20—30 feet deep, mentioned by Hacket.[1]

Iron.

Jhaj. Iron has been worked in the distant past near Jhaj, 2 miles to the south of Hathori (27° 0′ : 77° 10′), in a great trench. The ore was probably a breccia cemented by hematite, as seen in the grits adjoining. It is too impure to be of any value at the present day.

Mandnaoj. On the top of the plateau above Toda Bhim, near Mandnaoj, a small quantity of a substance called *kachéra* is worked by an Agra contractor, who is said to use it, presumably pulverised, to give weight and colour to lac bangles. It consists of small nodules and plates of reniform

[1] *Rec., Geol. Surv Ind.*, XII, p. 247.

hematite (perhaps manganiferous), formed as concretions and infillings in the joints of the quartzites. and weathered out into the thin soil covering the rock.

Steatite (*ghia bháta*).

Gisgarh.

The steatite quarry is in the scarp of Alwar beds immediately west of the town. It opens up a very small mineral body and has not been worked for fifteen years, as the pieces got out became too small for the manufacture of toys and plates. The steatite could only be followed for a short distance along its strike, the rest being covered with scree from the quartzites above; its greatest thickness is 2 feet. It behaves like a sill, splitting into two and running along the strike of the quartzites, which here have in them bands of schist and limestone. Its colour is rather dark green and it is much more impure and in much less amount than the occurrences of Morra-Bhandari (*infra*) and Dogetha in Jaipur.[1]

Kawa.

¼-mile to the west of Kawa (1 mile west-south-west of Moroli, 26° 46′: 76° 34′) a considerable amount of steatite was dug out of a deep well sunk at the foot of the dip-slope of Alwar quartzite; it is nowhere exposed at the surface.

Mora-Bhandari.

These are the deposits referred to by Hacket[2] as the source of the stone used by the Agra stone-carvers. They extend for about 5 miles near the base of the Alwar scarp between Dhota (26° 48′: 76° 48′) and Morra (26° 49′: 76° 52′). The workings are in the richer pockets of a stratum of talcose schist, which I have suggested (p. 185) may be derived from the underlying Aravalli rocks by concentration on re-deposition. The first excavation is immediately to the west of Dhota, in a bed about 25 feet thick. The steatite is harder than that of Dogetha in Jaipur, and has in it thin films of calcite, but hardly any pink iron staining. There seems to be present a little kaolin and perhaps disseminated quartz. In colour it is white or pale green. It has a vague foliation along the strike, but no jointing is apparent. This mine is now closed; formerly its output is said to have gone to the Punjab. Between Dhota and Morra are five or six places where the same bed has been opened up

[1] *Mem., Geol. Surv. Ind.*, XLV, p. 125.
[2] *Rec., Geol. Surv. Ind.*, XIII, p. 250.

but a locality at 1 mile to the west of Morra is the only place at which any work is being done. The contractor, Johari Lal of Agra, was said to pay a rental of Rs. 830 per annum to the Jaipur State and to export about 20,000 maunds annually; royalty works out therefore at ⅝ annas per maund; excavation and loading on carts costs 1½ annas per maund and cartage to Hindaun City Station 3 annas. The total cost, to the railway, is therefore 5⅛ annas per maund or Rs. 9 per ton. My figures were obtained from the workmen and may not perhaps be accurate. The contractor endeavours to get large blocks, and compact, rather hard stone of a greenish colour is most appreciated. As it is inconceivable that the demand for the familiar models of the Taj and other Agra curiosities can account for 20,000 maunds per annum, Agra must, if my figures are correct, be a distributing place for its use in other industries such as soap-making, rice-polishing, and sizing and weighting cloth. The Morra mine is an adit going a long distance into the hill, and branching into two at about half-way in. No information as to the shape of the deposit or its relation to the other rocks could be obtained. The hard cellular masses of iron-stained quartz or calcite are not nearly so common as at Dogetha; they are quite irregular both in shape and distribution.

Kaolin and pipe-clay (*khari*).

Rasnu.

At 1¼ miles to the south-east of Rasnu (26° 41′ : 76° 37′), a long and spacious tunnel has been driven along the strike of a bed of kaolin, which runs midway in the ridge of Alwar quartzites. It is about 60 feet thick, white but rather impure, and banded with quartzite. There is a very large quantity available, but it has been quarried for local purposes only, such as white-washing.

Mathasur.

Kaolin is also dug from the soft argillaceous and talcose zone near the base of the Alwar series in the ridge joining the Biana and Lalsot hills, chiefly near Mathasur (26° 55′ : 76° 59′). There are two beds, separated by quartzite, the upper yielding a white and fairly pure clay, slightly mottled with pale purple and pink.

Thermal Springs.

There are several sources of hot water in the Lalsot hills, none of them gaseous or mineralised. That at Moran (Garh) is well-known

and perennial; it is tapped and flows into a masonry tank. Near Gunah (26° 47′ : 76° 41′) is a well the water of which is slightly warm, as is also the case in several of the wells below the hill at Toda-Bhim, while those a short distance away on the plain are at the normal temperature; the former probably draw their supplies from rock springs and the latter from the ordinary sub-soil circulation. At Jaharo (26° 46′ : 76° 40′) is a *kund*, or masonry tank, the water in which is appreciably cold.

INDEX OF LOCALITIES.

—	Latitude.	Longitude.
Badalgarh	26° 53′	77° 18′
Bagren	26° 55′	77° 13′
Barhika	26° 55′	77° 14′
Berod	26° 51′	76° 49′
Biana	26° 55′	77° 21′
Damdama	26° 55′	77° 20′
Dhota	26° 48′	76° 48′
Gisgarh	26° 53′	76° 42′
Gudho	26° 47′	76° 43′
Gobindpur	26° 57′	77° 10′
Gunah	26° 47′	76° 41′
Hathori	27° 0′	77° 10′
Jaharo	26° 46′	76° 40′
Jhaj	26° 58′	77° 11′
Kamalpur	26° 48′	76° 49′
Karawli	26° 57′	77° 9′
Karomar	26° 39′	76° 30′
Kondra	26° 57′	77° 2′
Lakhanpur	26° 59′	77° 13′

—	Latitude.	Longitude.
Lalsir	26° 45′	76° 39′
Lalsot	26° 34′	76° 23′
Lauali	26° 34′	76° 33′
Mathasur	26° 55′	76° 59′
Moran (Garh)	26° 43′	76° 36′
Moroli	26° 46′	76° 34′
Morra	26° 49′	76° 52′
Nithahar	26° 58′	77° 6′
Pahari	26° 47′	76° 56′
Pail	26° 45′	76° 40′
Rasnu	26° 41′	76° 37′
Sita (Silagaon)	26° 59′	77° 11′
Talchiri	26° 54′	77° 5′
Toda Bhim	26° 55′	76° 52′
(Wer Wair)	27° 1′	77° 14′

ON THE ORIGIN OF THE LATERITE OF SEONI, CENTRAL PROVINCES. BY THE LATE R. C. BURTON, B.SC., F.G.S., I.A.R.O., *Assistant Superintendent, Geological Survey of India.* (With Plate 13.)[1]

THE laterite, whose origin is discussed in this paper is of the so-called high-level type and occurs at elevations between 1,900 and 2,100 feet above sea-level. The main outcrop lies a short distance south of Seoni and is 12 miles wide and 14 miles long, the village of Gopalganj being not far from the centre of it. Small outliers are found on all sides of the main outcrop and all occur at approximately the same level as the former (see Pl. 13). There can be no doubt that the whole of this laterite once formed part of a large sheet stretching from Seoni in the north to Katiapar and Chichaldoh in the south. The present topography of this part of Seoni is consequently due to the denudation of a plateau lying at an elevation of about 2,000 feet above sea-level.

Thickness of the laterite.

South of latitude 22° and east of the Seoni-Katangi road the laterite boundary is usually a sharp and well defined scarp and the thickness of the deposit is sometimes as much as 110 feet. In the north, however, the boundary becomes ill-defined as the country gradually decreases in altitude and the laterite is simply present as a thin soil-like covering on the surface of the Deccan Trap.

Description of the laterite.

In the great majority of cases the laterite is of the usual, well-known ferruginous cellular type traversed by vertical and ramifying tubes, which sometimes contain a soft grey or brown clayey substance. The colour varies from light to dark brown according to the percentage of iron. In addition to the above intermediate type we find comparatively rare outcrops of bauxite containing

[1] This paper by the late Mr. Burton was handed in shortly before he joined the Army in 1915. It was only meant to be a preliminary note which it was the author's intention to revise and enlarge before publication. Mr. Burton's death, from wounds received in action, has deprived the Geological Survey of a keen observer and clear thinker, and one who gave every promise of a brilliant scientific career. There is so much of interest in this note on the Seoni laterite, that it has been decided to publish it practically as he left it; it forms a valuable contribution to an aspect of the subject to which too little attention has hitherto been paid, *viz.*, the possibility of an aqueous origin for parts of the high-level laterite of India. EDITOR.

practically no iron, and of hematite devoid of alumina. Sections illustrating the occurrence of these varieties will be described later. In some cases the cellular ferruginous laterite is overlain by several feet of material mainly iron hydroxide, occurring in small pellets but containing no quartz grains; this variety seems to have been formed by the re-arrangement and slight transportation of the original laterite by rain water and may be similar to the "zone de concrétion" of Lacroix.[1]

Bauxite.

Light-grey and pink bauxite is frequently met with as boulders in streams flowing from the laterite scarp, but no considerable deposit was found. On the hill immediately south of Aturwani a bed of grey bauxite 20 feet thick lies between horizontally bedded ferruginous laterite. It is in parts veined with iron oxide but is of good quality. Blocks of 70-80 cubic feet lie on the hill-side but the extent of the deposit is quite small. The interesting point to note is that the bauxite is interbedded with laterite and must have had a similar origin. Among the blocks of bauxite met with in the streams oolitic varieties sometimes occur consisting of small oolitic grains of bauxite in a pink to dark granular matrix. One peculiar variety of bauxite was collected consisting of irregular, apparently brecciated, masses and veins of grey bauxite in a red or pink and slightly earthy matrix, which in places tends to be oolitic.

Oolitic iron-ore.

A deposit of oolitic iron ore was found on the hill south of Paraspani (21° 52′ : 79° 23′); so far as could be determined it is 30 feet thick and caps the hill, overlying cellular ferruginous laterite of the usual kind. The area covered by the ore may be roughly estimated as 100 yards by 50 yards, but could not be determined with any degree of certainty. The ore consists of an aggregation of oolitic grains ($\frac{1}{16}$ to $\frac{1}{8}$-inch in diameter) of hematite altering into soft yellow limonite. It has a specific gravity of 3·33, contains 75·8 per cent. ferric oxide and seems to be of fairly constant composition throughout.

Laterite conglomerate.

Among the ordinary cellular laterite conglomeratic types occur. On the hill near Panjra specimens of dark red laterite were collected containing rounded

[1] A. Lacroix: "Les Latérites de la Guinée, ...", *Nouvelles Archives du Muséum de Paris,* 5 sér., tome V, 1913.

pebbles of similar or slightly more aluminous composition in a highly ferruginous base. On close examination no concentric structure characteristic of oolites was noticed so that the rock is probably a true conglomerate. A similar laterite conglomerate was collected from the hill north of Chandarpur; it contains sand grains and consists of well rounded ferruginous pebbles in a red matrix, which in places is slightly earthy and is traversed by hollow cylindrical tubes. In many cliff sections of laterite, conglomeratic types occur at various horizons throughout the deposit. The matrix is almost always ferruginous and cellular, but the pebbles, varying in size from $\frac{1}{4}$-inch to three or four inches in diameter, consist of grey and pink bauxite, or of red bauxite containing a considerable amount of iron. They have evidently been derived from beds of different composition and re-deposited along with ferruginous silt, which now forms the matrix.[1]

Geological horizon.

The laterite, with its varieties bauxite and iron ore, is the youngest consolidated formation in the district and is found directly overlying Deccan Trap, Intertrappean chert, and the gneissic complex. It always occurs in horizontal beds, usually split up into blocks by well-defined vertical joints, and has evidently suffered no disturbance of dip since its formation. The vertical joints are often gaping fissures several inches wide probably produced by the contraction of the laterite during its consolidation. Considering first the main outcrop of laterite, it is found to overlie Deccan Trap except near Kohka Khera and Potla, where it overlies Intertrappean chert, and at Khapa and west of Dulal, where it comes directly into contact with the gneiss owing to the thinning out of the Deccan Trap. In the case of the laterite outliers, however, the underlying formation on the hills to the east and south-west is gneiss, with the single exception of Katiapar, where a thin bed of Deccan Trap about 30 feet thick intervenes. In the south-east of the area the base of the laterite overlying the gneiss is at elevations near 2,000 feet or more, being higher than in the north. It seems probable from the above facts that when the laterite first began to form, a sheet of Deccan Trap covered the main part of the area and thinned out to the south and south-east where gneissic rocks rose to higher levels than in the west.

[1] *Cf.* L. L. Fermor: *Memoirs, Geol. Surv. Ind.*, XXXVII, 1909, p. 375.

Boundary between the laterite and the gneiss; the occurrence of lithomarge.

Lithomarge and fine clays are comparatively rare under the laterite and only occur in certain cases when the trap is absent:—

(*a*) Lithomarge crops out on the right bank of the stream which flows S.S.W. across the Dulal forest-line just east of the point where the Pukhara line joins from the north. The deposit is approximately 30 feet thick and could not be traced for more than 50 yards. It is a pink or straw-brown clayey rock, in places containing pebbles of quartz and red chert, and lies under ordinary cellular laterite and over the gneiss. In parts it is quite quartzose passing into a ferruginous sandstone. Where this bed dies out the laterite comes into direct contact with the gneiss. There seems to be little doubt that this deposit is of detrital origin and is partly derived from the underlying gneiss. Specimens were collected showing the passage of gneiss into the sandy lithomarge and in these particular cases it would seem to have been formed by the alteration of the gneiss *in situ*. Whether this is due to the alteration of the gneiss by iron-bearing solutions infiltrating from the overlying laterite after its consolidation, or whether it was formed before the overlying laterite, is not proved; the evidence, however, is favourable to the former view.

(*b*) Ascending the scarp formed by the tongue of laterite at the foot of which lies the village of Dulal, we find a variegated reddish-brown clay overlying the gneiss of the Dulal valley. It is very fine-grained, extremely friable, weathers blue and is overlain by red cellular laterite. The thickness of the lithomarge is about 50 feet, its base occurring at a level of 1,950 feet. Its exact relationship with the gneiss is not seen, as the junction is covered by a recent deposit of quartzose laterite containing quartz pebbles, but it forms a fairly sharp line of division with the overlying laterite, which is about 90 feet thick. It is the only deposit of its kind found in the area. Under the microscope it is seen to contain very rare, small, angular grains of quartz and is mostly composed of a hydrated aluminium silicate. In the absence of an analysis and of evidence showing its connection with the underlying gneiss, it is impossible to form a definite opinion regarding the origin of this rock, but it seems probable that it is a fine clay, deposited in a small basin on the surface of the gneiss after the thin covering of Deccan Trap had been denuded off.

(*c*) At the base of the hill N.N.W. of Magarkatta a slightly

banded gneissose granite crops out. On ascending the hill from the north along the forest line, the gneiss is seen to underlie a bed, 10 to 20 feet thick, of bright-red earthy rock containing veins of a soft white substance, which on analysis proved to be kaolinite with a specific gravity of 2·52. In places the red rock has a speckled appearance and passes into what seems to be a breccia containing angular pieces of bauxite and rare fragments of almost pure iron oxide lying in a dull-red earthy ferruginous matrix. This deposit is overlain by about 90 feet of cellular ferruginous laterite and seems to be related to the lithomarges, but its exact method of formation is not known. It seems probable that the kaolinite is derived from the decomposition of the felspars in the original gneiss from which the deposit is largely derived. Its occurrence in veins and streaks proves it to have been deposited by water, circulating between the base of the laterite and the top of the gneiss.

Alteration of gneiss into laterite.

The laterite on Hathipat, the hill north of Chichaldoh, is very thin, consisting principally of blocks lying on the surface of the gneiss, which is generally quite fresh and unaltered. A specimen was collected showing a fine-grained gneiss passing into a kind of ferruginous quartz-rock; the felspars are being kaolinised and ferric oxide fills in the interspaces between the quartz grains; the end-product, after the elimination of the kaolinite in solution, would be laterite containing quartz grains. It is significant that with the removal by denudation of the main mass of laterite, which must formerly have been several hundred feet thick, the conversion of the top of the gneiss into laterite seems to have stopped short of completion, thus indicating that it is probably due to the infiltration of solutions containing iron and carbon dioxide in solution derived from the overlying laterite. In this case therefore the conversion of the gneiss into laterite *in situ* is a secondary process and is not to be considered in relation to the formation of the main body of laterite whose origin we are discussing.

Bedded deposit at the base of the laterite.

On the hill N.W. of Sukla no good section could be examined owing to the prevalence of laterite débris on the hillside, but the base of the laterite can be determined approximately as the point where the fragments of quartz cease to be found. The total thickness of the laterite is thus about 100 feet and at its base a

curious bedded deposit occurs. It is a heavy dark-red rock, which on a fresh fracture is seen to be composed of alternating laminæ of grey and red colours never more than $\frac{1}{16}$ inch wide. Under the microscope the alternating red and grey laminæ are seen to be composed of bauxite containing a little identifiable gibbsite coloured in the case of the former with iron oxide. The rock is a fine-grained aqueous deposit laid down in still water. Overlying it is a thick mass of cellular laterite containing rare nodules of bauxite.

Occurrence of quartz in the high-level laterite.

Quartz was noticed in association with the laterite in the following places:—

(*a*) on the hills south-east of Barghat;
(*b*) on the hills east of Dalal;
(*c*) on the hill north-east of Chandarpur;
(*d*) one mile south of Durli Chattarpur.

(*a*) and (*b*). In these cases the laterite is of the cellular type with well-developed hollow tubes, and on a fresh fracture shows patches of light yellow limonitic material in a dark red matrix. Scattered throughout the rock, particularly near the top, and undoubtedly forming part of the original deposit, are angular and sub-angular quartz grains, which are quite conspicuous in the hand-specimen. These quartz grains are rather irregularly distributed being absent from the small purer nodules, which are usually explained as the result of segregation. It seems probable that the quartz and laterite were deposited together under water and that subsequently part of the material was segregated by solution to form the ferruginous nodules, leaving the insoluble quartz grains in the matrix. In both the above cases the laterite overlies gneiss. The quartz grains are the same in shape and size as those found in certain river terraces composed of quartzose laterite in the district of Balaghat.

(*c*). Here the laterite occurs as a capping on the hills of gneiss and is sometimes 60 feet thick. In general it is identical with that described in the above cases, but at one point, at an altitude of 2,100 feet, a thin bed of dark red ferruginous sandstone (identical with the so-called low-level or quartzose laterite) was found interbedded with the laterite. The quartz grains are sub-angular and evenly distributed throughout the rock, which is certainly a water deposit. This bed could not be traced far, but its

occurrence in this position is strong evidence that the laterite itself was also deposited under water.

(*d*). I am indebted to Mr. M. Vinayak Rao of the Geological Survey of India for a specimen of lateritic grit collected from a point east of the Seoni-Katangi road, one mile south of Durli Chattarpur. He informs me that it occurs as blocks lying on the surface of the Deccan Trap and is apparently the remnant of a fairly extensive bed, about six inches thick, forming the base of the laterite; it was not found, however, actually overlain by the ordinary laterite. The rock consists of angular and rounded pieces and grains of quartz in a dark, ferruginous matrix containing a small amount of limonite and patches of white chert showing concentric structure. The weathered surface of the specimen is pierced by hollow, tubular holes characteristic of the laterite forming the greater part of that outcropping in Seoni. This rock seems to be comparable with the lateritic conglomerate containing rounded pebbles of khondalite in a pisolitic matrix recorded by C. S. Middlemiss as occurring at the base of the laterite in the Vizagapatam Hill Tracts.[1] The importance of the Seoni specimen is increased by the fact that there are no gneiss outcrops within 3¼ miles, although the quartz grains must have been laid down under water draining from off a gneissic surface. The only feasible explanation of this is that the rivers bringing the sediment into the lake in which the laterite was deposited, flowed from the south or south-east—all the country to the north, east and west having formerly been covered by trap—where gneiss must have been exposed on the edge of the Satpura plateau even at the beginning of the period during which the laterite was formed.

Oolitic laterite.

Many theories have been brought forward to account for oolitic and pisolitic structures and the majority of them, dealing particularly with siliceous and calcareous oolites, ascribe their origin to the deposition of a sediment in concentric films as a result of the agitation of the water, or to the action of certain organisms on a deposit in process of formation. There seems no doubt that the above theories can be correctly applied in the case of siliceous and calcareous oolites, but they have not yet been definitely proved to hold during the formation of iron ores and laterite. Villain in 1899 and Rolland

[1] *Ann. Rep., Geol. Surv. Ind.*, 1902-03, p. 25.

in 1901 [1] ascribed the origin of oolitic iron ore to the precipitation of iron oxide from a solution of ferrous carbonate in water saturated with carbon dioxide on coming into contact with sea-water agitated by currents; the movements of the sea-water during the formation of the precipitate caused the ore to collect in concentric films.

The pisolitic iron ores of Antrim, Ireland, are said by Forbes [2] to be indirectly derived from the basalt and he points to the formation of pisolitic ores in the Swedish lakes at the present day as due to the action of confervoid algæ. Mallet [3] suggested that the iron ores in Indian laterite were deposited in lakes on the surface of the Deccan Trap; the iron passed into solution as ferrous carbonate through the agency of decomposing vegetation and was re-precipitated in the lakes after being oxidised to hydrated ferric oxide.

C. W. Hayes,[4] writing of the bedded bauxite deposits of the Southern Appalachians, attributed their pisolitic structure to the collection of the precipitate of hydrated aluminium oxide into globules due to the motion of ascending water.

H. Coquand, [5] in a paper entitled "Sur les bauxites de la Chaîne des Alpines et leur âge géologique," shows that these bauxites, which are sometimes pisolitic, are interbedded with pisolitic limestones, sandstones and calcareous gritty clays and must have been deposited under somewhat similar conditions.

In his recent work "Les latérites de la Guinée," A. Lacroix [6] while admitting that calcareous and siliceous pisolites can be formed by the deposition of the sediment in agitated water, denies that this is possible in the case of laterite and states that the formation of pisolites in laterite is due to phenomena of concretion. In the case of laterite formed *in situ* this concretionary action is undoubtedly of the greatest importance, but where we are dealing with lacustrine deposits, either chemical or detrital, the evidence points to the formation of pisolites as original structures at the time of formation of the deposits. The case of the Swedish iron ores is quoted by Lacroix without his expressing an opinion on it, but it seems probable that they are chemical deposits with an

[1] *Cf.* L. Sudry: *Bull. Soc. Linn. Normandie*, 1908, p. 17.
[2] Cf. *Rec., Geol. Surv. Ind.*, XIV.
[3] *Rec., Geol. Surv. Ind.*, XIV.
[4] *Trans. Amer. Inst. Min. Eng.*, XXIV, 1894.
[5] *Bull. Soc. Geol., France*, 1870-71, p. 98.
[6] *Nouvelles Archives du Muséum de Paris*, 5 *série, tome V, 1913, p. 341.

original pisolitic structure due to the deposition of the iron oxide in concentric films.

In addition, pisolitic laterite is now forming in many small streams in India,—being actually found in the watercourses and not higher up the banks or above the level of running water: this laterite must be regarded as having been deposited from solution in the water of the streams. It is pisolitic from the time of deposition and does not owe its formation to subsequent concretionary action.

The high-level laterite of Seoni was probably partly a chemical and partly a detrital lake deposit. Hitherto oolitic and pisolitic structures have only been observed to occur among the bauxites and iron ores and not in the more impure, siliceous and ferruginous laterite of the common type. In this case, also, these structures seem to be largely a result of the deposition of sediment from solution: the cellular laterite being mainly formed from detritus derived from the Deccan Trap and carried into a lake. In Seoni the pisolitic types occur at various horizons throughout a thickness of over one hundred feet of ferruginous cellular laterite and are interbedded with it. Facts of this kind are difficult to explain by assuming subsequent concretionary action, since only parts of the deposit, sometimes bauxite, sometimes iron ore, are affected. By admitting, however, that the laterite was partly a chemical and partly a detrital deposit in a lake, this difficulty disappears. But when we examine the uppermost portion of the laterite it is often seen to be composed for a depth of a few feet of an agglomeration of small pisolites, which have been formed by concretionary action due to the solution and subsequent re-deposition of the laterite by infiltrating rain water. This "zone de concrétion" near the surface passes down into the cellular laterite containing ramifying tubular holes, showing it to be of secondary origin and different from the original pisolitic laterite mentioned above.

The above facts, which will be discussed more in detail later, seem to prove that the high-level laterite and associated lithomarges and ferruginous sandstones of Seoni were all deposited in water under similar conditions. It now remains to be seen whether we can obtain any evidence as to the nature of the sheet of water in question.

Those familiar with laterite in the field will readily admit the

probability that the area enclosed by the broken line in Plate 13 was formerly an elevated plain about 2,000 feet high covered by one large sheet of laterite. From considerations deduced below it seems probable that the laterite never extended much beyond its present limits.

North of the town of Seoni the larger part of the district is covered by Deccan Trap and occasionally rises to heights of nearly 2,400 feet and yet, though the conditions seems to be so favourable, no laterite occurs. On the theory that the laterite was formed from the trap by alteration *in situ,* this absence of laterite in the northern part of the district is inexplicable; but if we admit that it was deposited in a lake whose boundaries are approximately represented by the broken line in Plate 13, the anomaly is explained at once. Similarly, small outliers of laterite occur on the gneissic hills north of Bhojiapar near the road from Chirchira to Jam at elevations between 1,950 and 2,000 feet, the base of the laterite in the case of the largest outliers being at about 1,980 feet. To the south and west of these outliers there are several hills, rising to heights greater than 2,000 feet, composed of porphyritic biotite gneiss without a capping of laterite. The shore-line of the old lake must therefore have run between these hills and the present outcrops of laterite, the hills above 2,000 feet having formed part of the barrier holding up the lake.

Relation between the Satpura plateau and the Nagpur plain.

This question cannot be discussed in detail at present but it will suffice to state that during the field-season 1913-1914 it was proved that the Satpuras are an old mountain range, which was produced by thrusting from the north or north-west, the Nagpur plain acting as a *horst;* the rocks of both plain and plateau being identical. It cannot be proved that this thrusting is responsible for the difference of 1,000 feet between the heights of the Satpura plateau and the Nagpur plain and it is quite possible that block-faulting on a large scale since the Deccan Trap period has caused the Nagpur plain to be depressed relatively to the plateau. The only normal faults detected in the area are near Alisur and Tikari. Near Alisur the trap ends in a narrow arm pointing E.N.E. towards Sukhadongri; south of the village there is an outlier of trap, the base of which is fifty feet higher than that of the main outcrop; the southern boundary of the trap here is therefore a fault throwing north. Taking into consideration the

levels of the top of the gneiss it was also proved that the northern trap boundary is a fault throwing south, thus combining with the former to make a trough fault.

On the hills between Tikari and Paraspani and on those immediately south of the latter village down to Katiapar, the base of the laterite is at a level of 1,900 feet, which is about 100 feet lower than the base of the laterite north and north-east of the line FF. It seems probable therefore that the area to the south of the line FF has been faulted down about 100 feet since the formation of the laterite.

Very recent uplift of the whole area of Balaghat and Seoni can be proved from a study of the terraces of alluvium along the river-banks. In some parts two terraces occur, one 10 feet and the other 25 feet above the present level of the river, showing that quite appreciable elevation of the land has occurred in very recent times.

Amount of denudation since the formation of the laterite.

In between the outliers of laterite on the hills near Tikari, Paraspani and Kandlai, the level of the gneiss is often more than 200 feet lower than the level of the base of the laterite. which overlies gneiss. This indicates that at least 200 feet of rock has been removed since the formation of the original sheet of laterite. In some cases, however, the amount of denudation has been greater than this; about one mile N.E. of Kandlai are two small hills about 1,750 feet high rising more than 200 feet above the surrounding gneissic area; these hills are covered by low-level quartzose laterite containing rounded pebbles of quartz and evidently of detrital origin, though of a different type from the high-level laterite discussed in this paper. This low-level laterite has been derived from the high-level laterite by the accumulation in streams of material denuded from the latter,—a process which is going on at the present day; it is consequently younger than the high-level laterite mentioned above; therefore at least 250 to 300 feet of rock material must have been denuded away since the formation of the original laterite area.

Present day formation of laterite.

A study of the laterite now in process of formation on the Nagpur plain in Seoni and Balaghat districts confirms the above evidence as to deposition under water. In most cases this laterite contains angular and subangular blocks and fragments of quartz.

The greater part of it is found as flat terraces and on the low watersheds between the sluggish streams characteristic of this plain. In the case of the smaller rivers the laterite forms in the stream-beds and is then generally accompanied by nodules of *kankar*, which, however, are separate and do not form part of the laterite.

In addition, small rounded pisolites of iron oxide, sometimes showing concentric structure, often lie thickly scattered over the surface of the alluvial soil and in cuttings on the edges of streams they are occasionally found distributed throughout the soil. The massive forms of this laterite are generally cellular in structure, consisting of an agglomeration of rounded pisolites of iron oxide, which have been partly dissolved and re-deposited to form a cement in which the quartz grains occur. Quartz is rarely found inside the individual pisolites.

In some cases the laterite contains large rounded nodules, besides the small pisolites, and might then be termed a laterite conglomerate. Some of the larger, rather irregular, nodules contain a nucleus of bauxite covered on the outside by limonite; others, when broken open, effervesce with acids, probably owing to the presence of iron carbonate which has been preserved from oxidation. The method of formation of this laterite seems to be as follows :—

Iron oxide and alumina together with lime are leached out of the rocks, and probably also out of the soil, in the catchment area of a stream and are carried down as carbonates in solution. When the river overflows its banks, forming spreads of alluvium, the detrital material is impregnated with the solution containing the above substances. As the alluvium dries up the solution becomes concentrated and iron oxide and alumina are precipitated, followed by lime carbonate yielding *kankar*. The oxidation of the ferrous carbonate to ferric hydrate is not always complete as is proved by the occurrence of small amounts of carbonate in the interior of the larger nodules in the laterite. The iron and aluminium hydrates are precipitated as pisolites owing to a tendency to collect round centres of deposition. This is the first stage in the formation of the laterite. Subsequent resolution and re-deposition by infiltrating water brings these pisolites together and they consolidate as the laterite we now see.

In the same way the laterite formed in the beds of streams is probably deposited from solution in carbonic acid and then

consolidated. It generally occurs where the water is agitated by passage over stones, or down a steeper part of the bed, thus indicating that the bringing of a large surface area of water into contact with the oxygen of the air is an important factor in the precipitation of the laterite.

The association of *kankar* with the laterite[1] suggests connection between the two, and it seems possible that the calcium carbonate aids in the precipitation of the iron and aluminium hydrates.

Conclusion.

The object of the present paper is to prove that the laterite of Seoni was accumulated in a lake and to discuss the changes in topography that have taken place since its deposition. The following arguments are adduced—

(1) the laterite is identical in composition whether it overlies Deccan Trap or gneiss, and in each case bauxite and iron ores occur in small quantities at various horizons in the cellular ferruginous laterite;

(2) the alteration of gneiss, *in situ*, into laterite has been observed, but is always negligible in amount and can be best explained as due to subsequent infiltration of iron-bearing solutions from the overlying laterite into the gneiss;

(3) fine clays, most probably aqueous deposits, are sometimes found at the base of the laterite;

(4) the laterite at the base of the deposit occasionally displays well-defined bedding;

(5) in certain cases the laterite overlying Deccan Trap contains quartz grains; and, in one locality, where the laterite overlies gneiss, a ferruginous lateritic sandstone was interbedded with it. The quartz-bearing laterite occurs in the middle and near the top of the deposit as well as near the base; these quartz grains are consequently not derived from gneiss changed into laterite *in situ*;

(6) near Durli Chattarpur a conglomerate containing quartz pebbles in a lateritic matrix lies on the surface of the Deccan Trap and probably forms the basement bed of the laterite;

[1] *Cf.* T. H. Holland, *Geol. Mag.*, 1903, 59.

(7) the occurrence of conglomerates consisting of pebbles of bauxite of varying composition in a ferruginous matrix can only be explained by deposition in water;

(8) oolitic bauxite and oolitic iron ore are found interbedded in the laterite, and, near Aturwani, a bauxite bed showing traces of oolitic structure was found with cellular ferruginous laterite above and below it;

(9) a large tract of Deccan Trap lying to the north of the laterite is quite free from the latter, although, reasoning from its position and elevation and neglecting for a moment the theory of deposition in a lake, there would seem to be no reason why laterite should not be found there. In addition, hills of biotite gneiss with no laterite capping lie a short distance south and west of the extreme easterly laterite outliers and rise to heights of more than 50 feet above the level of the laterite. They must have formed the high ground on the southern edge of the lake in which the laterite was deposited;

(10) a study of certain laterites in process of formation at the present day indicates that they are largely due to the solution of the constituent oxides in streams and their subsequent deposition therefrom. These modern laterites formed in the beds of streams are often pisolitic;

(11) the theory that high-level laterite is sometimes formed by deposition in lakes is not new, but has been previously advocated in papers dealing with Indian laterites. It was brought forward by Mallet [1] who showed that a decided resemblance existed between the iron ores of Antrim and those occurring in Indian laterite. In 1902, C. S. Middlemiss was of the opinion that the high-level laterite of parts of the Vizagapatam Hill Tracts was a sedimentary deposit laid down in water; it occurs at a "fairly constant level, surrounding the hills like a shore belt through which the bare rocks now rise to superior heights like islands in the laterite age." [2] E. W. Wetherell[3] considers that the laterite near Bangalore was laid down in an old lake, which

[1] *Rec., Geol. Surv. Ind.*, XIV, p. 139.
[2] *Ann. Rep., Geol. Surv. Ind.*, 1902-03, p. 25.
[3] *Mysore Geol. Dept., Mem.*, III, pt. 1.

he terms the "Hoskote Lake;" he further states that the laterite formed *in situ* in this area is of very small amount and is due to the infiltration of solutions containing iron oxide from the overlying deposit of lacustrine laterite. This argument also applies to those cases in which the Seoni laterite is found to show a passage into the underlying trap or gneiss. Lastly L. L. Fermor [1] after a study of the laterite of the Yeruli plateau, Satara district, decided that part of it, including a conglomerate consisting of bauxite pebbles in a pisolitic, ferruginous matrix, was deposited in a lake.

[1] *Mem., Geol. Surv. Ind.*, XXXVII, 1909, p. 375.

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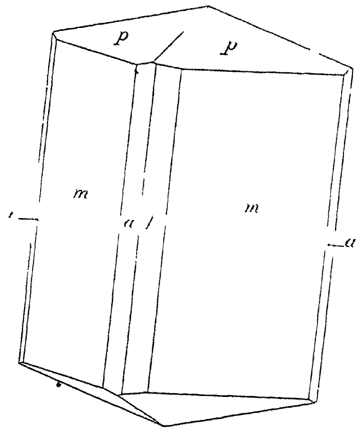


Fig 1

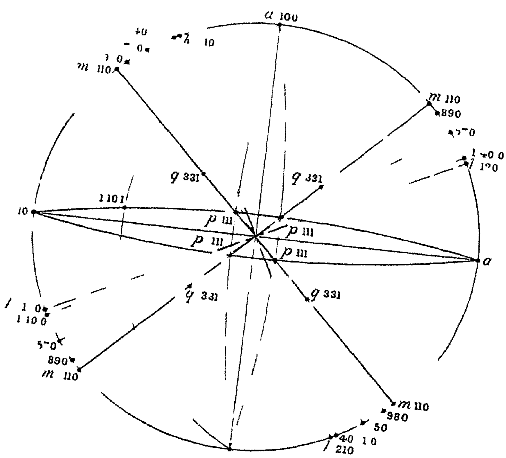
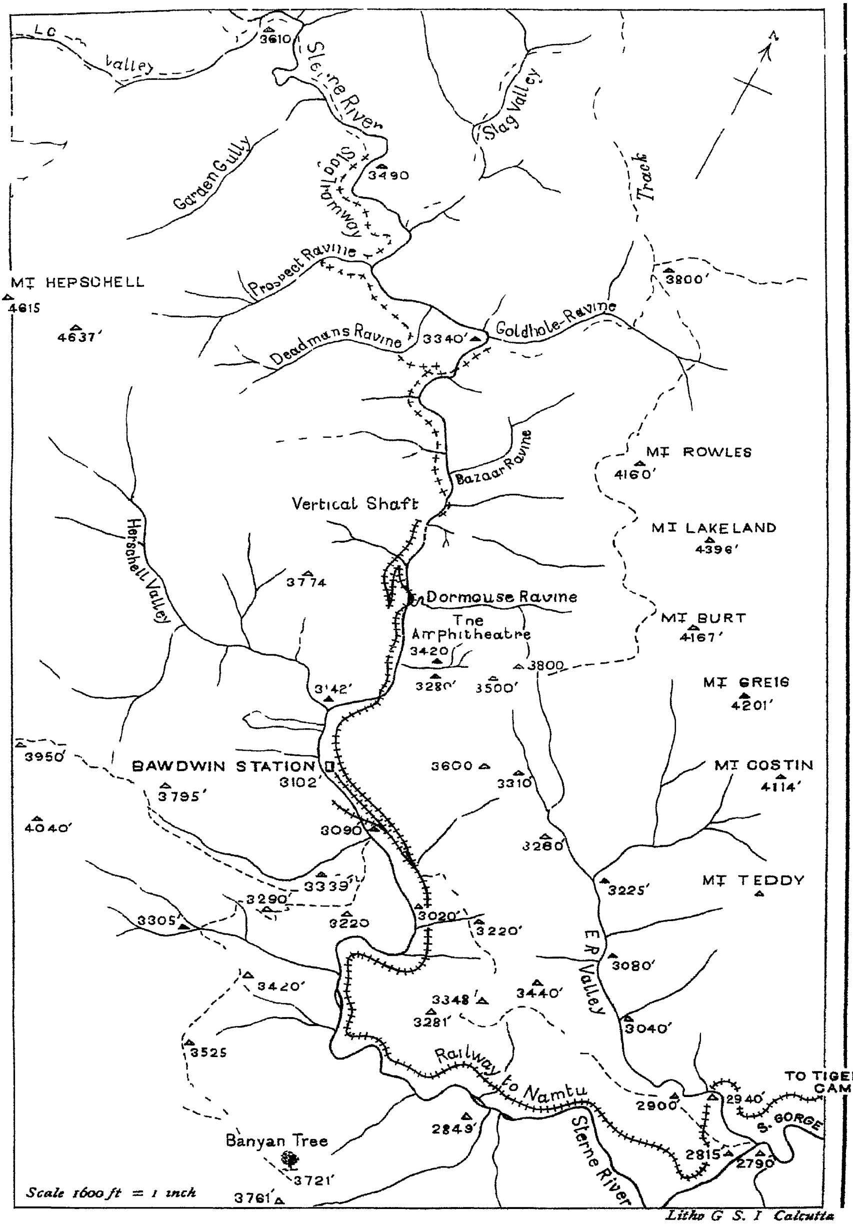


Fig 2

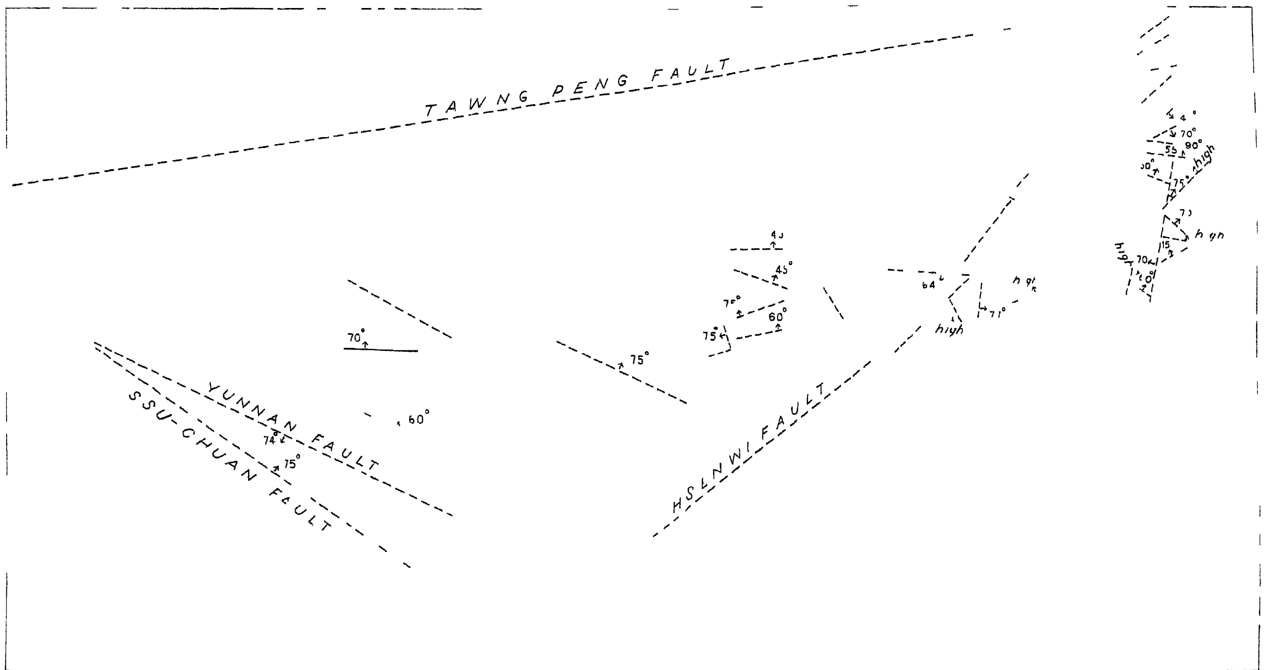
G S I Calcutta

HOLLANDITE FROM KAJLIDONGRI, JHABUA STATE, CENTRAL INDIA.



MAP OF THE BAWDWIN MINES.

Supplied by the Burma Mines Ltd., from a survey by Dr. J. M. Maclaren.

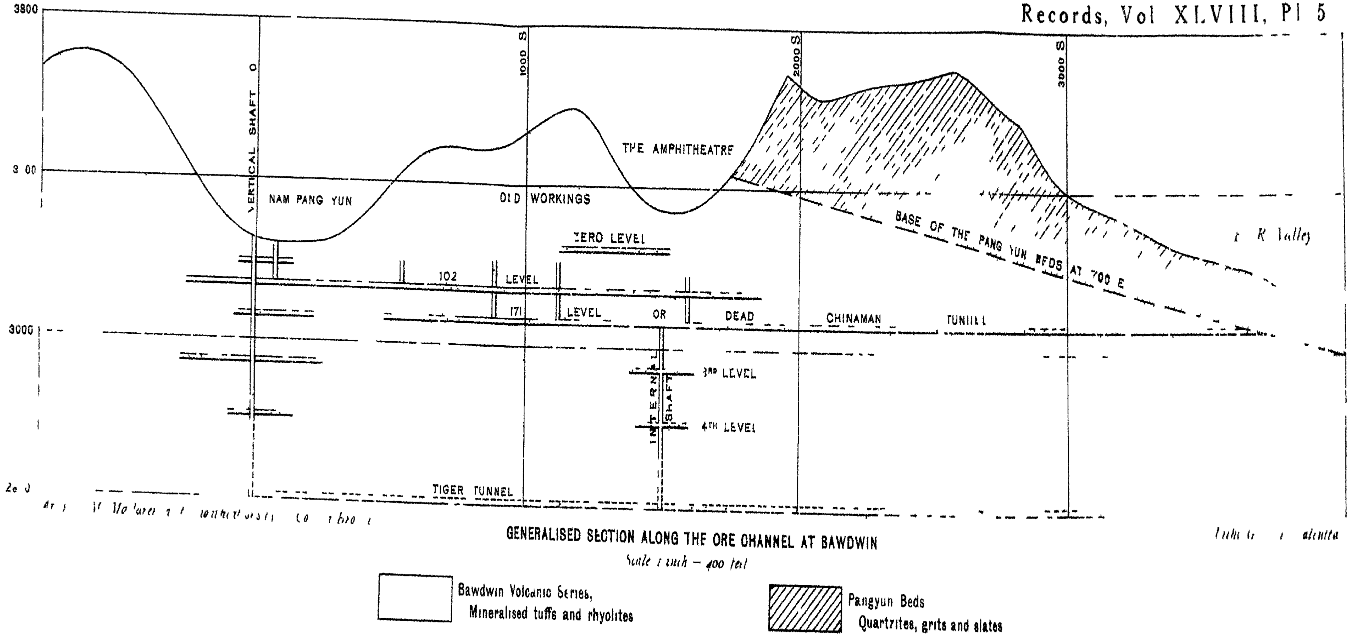


From the Company's plan

Litho G S I Calcutta

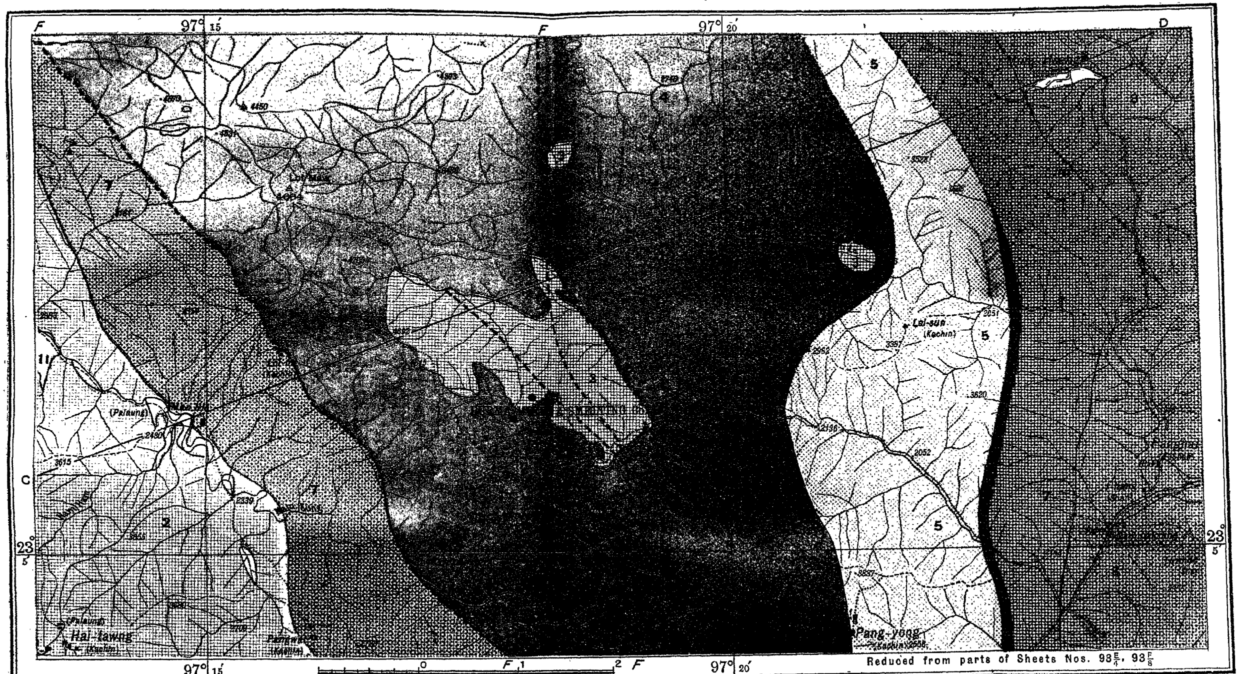
FAULTING ON THE 171′ LEVEL

Records, Vol XLVIII, Pl 5



GENERALISED SECTION ALONG THE ORE CHANNEL AT BAWDWIN

Scale 1 inch – 400 feet



By J. Coggin Brown.

Col. prtd. G. S. I. Calcutta.

BAWDWIN MINES.

INDEX.

11 RECENT & SUB-RECENT

8 PLATEAU LIMESTONE

Dips

7 NAMHSIM SANDSTONES

PANGHSAPYE GRAPTOLITE HORIZON

Approximate directions of main Fault trends

5 NAUNGKANGYI BEDS

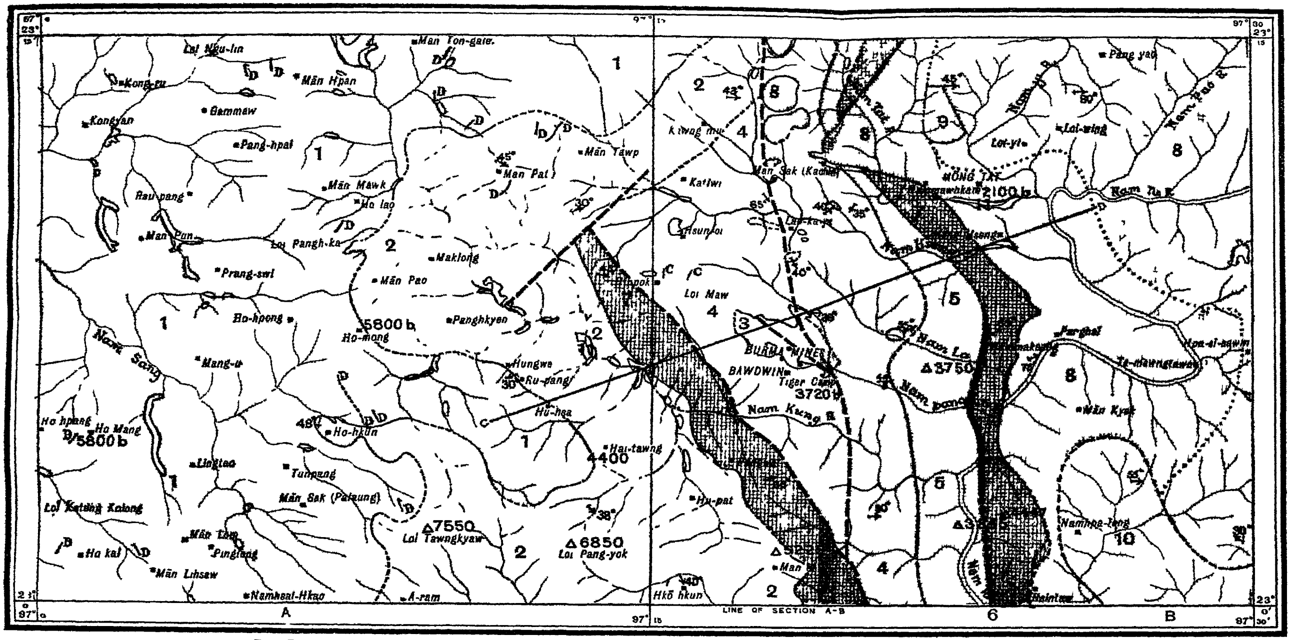
PANGYUN BEDS

3 BAWDWIN VOLCANIC SERIES

2 CHAUNG MAGYI SERIES

Boundaries undefined

Records. Vol. XLVIII, Pl. 8.



Geology reduced from Sheets No $93\frac{E}{8}$ $93\frac{E}{4}$ Scale 1 in = 1 m -- —Topography taken from S E Frontier Sheet No 4, N W Scale 1 in = 4 miles

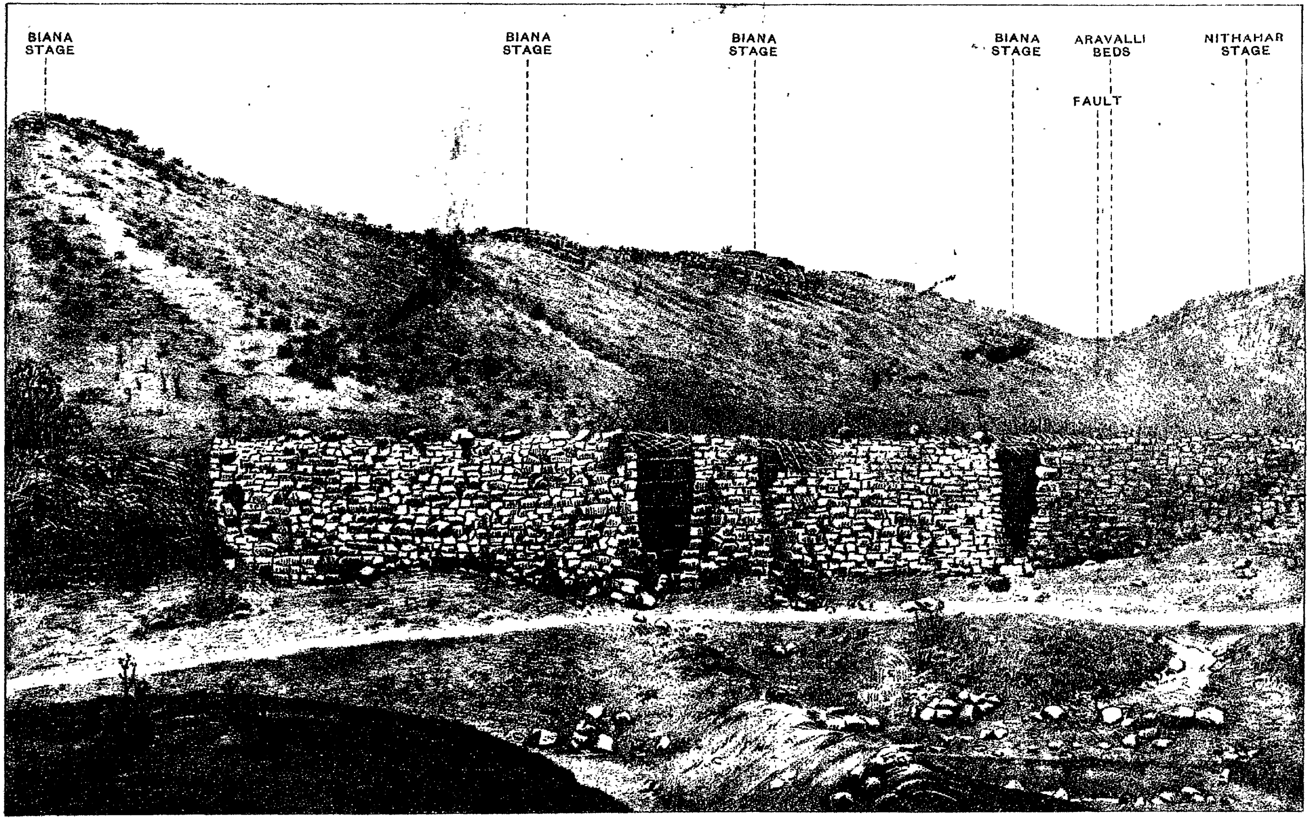
Colour prtd G S I Calcutta

GEOLOGICAL MAP SHOWING BAWDWIN AND SURROUNDING COUNTRY.

Scale 1 inch = 4 miles.

BY

J. COGGIN BROWN.

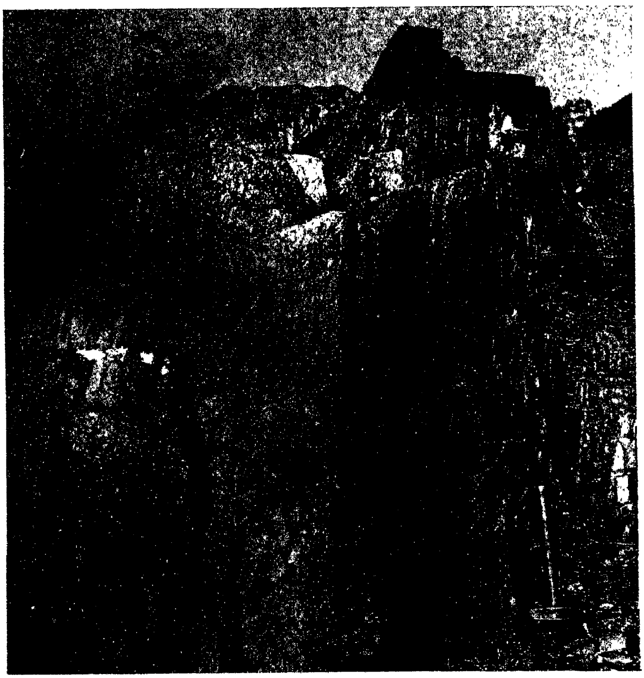


From a photograph by A. M. Heron *Litho G. S. I. Calcutta.*

ARAVALLI SYSTEM, NITHAHAR, BADALGARH AND BIANA STAGES.

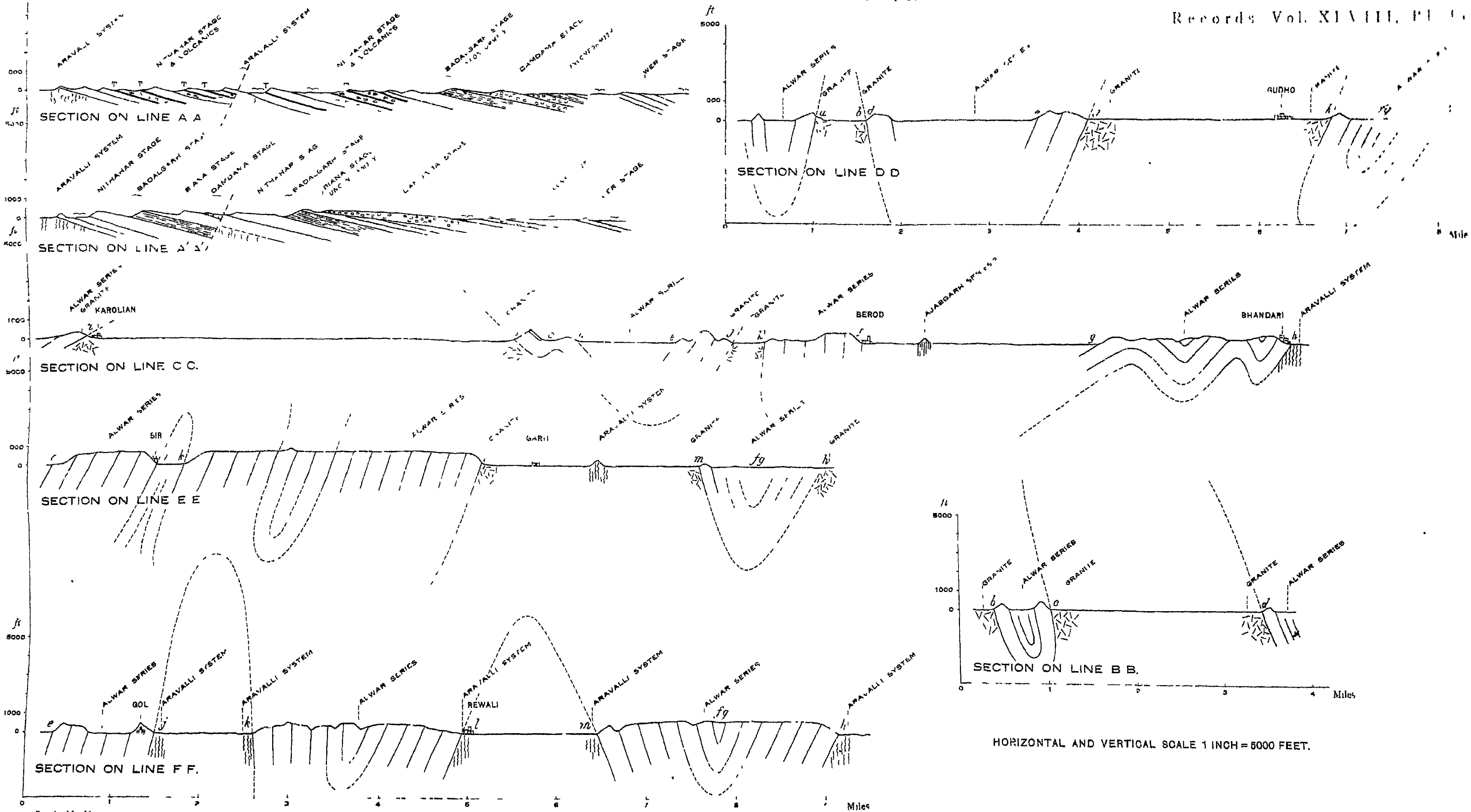
Barhika near Bagren (looking north-west.)

FIG. 1. NITHAHAR QUARTZITE UNCONFORMABLE ON ARAVALLIS NITHAHAR (Looking North.)



Photographs by A. M. Heron. *G. S. I. Calcutta*

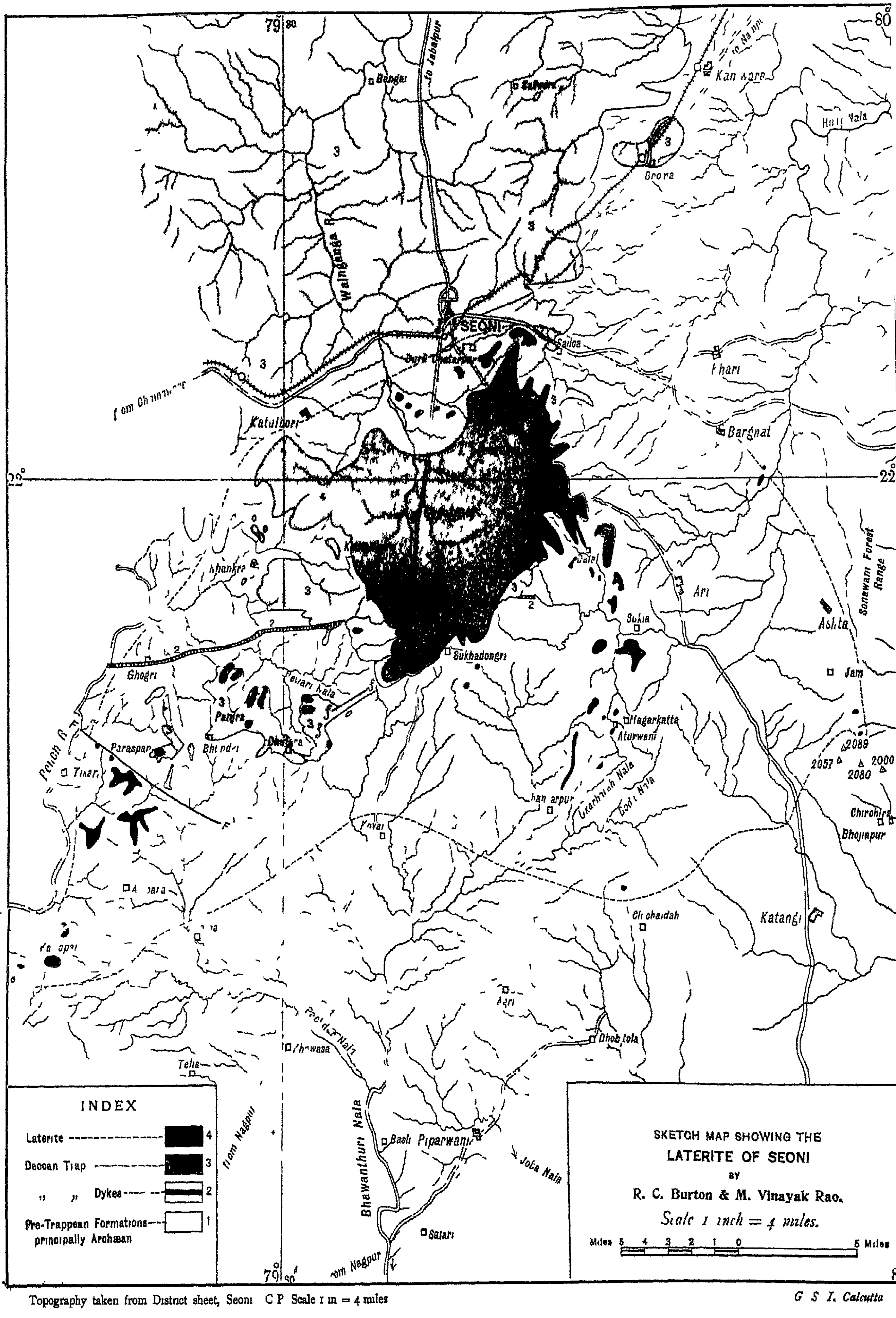
FIG. 2. VERTICAL ALWAR QUARTZITES, (right,) UNCONFORMABLE ON ARAVALLI SCHISTS, (left.) LALSOT (Looking North-West.)



HORIZONTAL AND VERTICAL SCALE 1 INCH = 5000 FEET.

By A. M. Heron

Litho G. S. I. Calcutta



Topography taken from District sheet, Seoni C P Scale 1 in = 4 miles

G S I. Calcutta

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